ERGIS DATA BANK FOR LAND AND RESOURCE UTILIZATION

BY

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1.1. Study Intent

The purpose of this study is to establish an Environmental Resources Geo-Information System (ERGIS) data bank for land and resources utilization. The development of an ERGIS data bank, thus, relates to the characteristics of land and resources planning. The specifications and functions of ERGIS cannot be defined and standarized until the methodology of land and resource utilization is described in detail.

The relationship between a data bank and land use planning is a servant and master situation. The data bank is the tool to carry out the ultimate goal of land use planning. Sometimes, due to certain difficulties, financial and/or organizational, one has to work with the hardware or software that is available. It is important to know in advance whether this hardware or software system can accommodate the planning need. It could be a serious mistake to shape the land use methodology according to the available software and hardware systems. The methodology can only be modified to an extent that does not alter the final results. If alteration does occur, the redevelopment of the hardware or software system is required.

The purpose of utilizing the ERGIS data bank, or any other type of land use planning data bank, is to increase work efficiency and to add the capability of handling complex environmental data for resources management and decision-making. In other words, the justification for establishing an ERGIS data bank can be categorized as follows/1:

1) The need to convert all resources information into digital form for data manipulation.

/1 Certain points from Keynote Address to International Conference on Automation in Cartography by W.A. Radlinski, Associate Director, U.S. Geological Survey, December 9, 1974, have been incorporated.

In order to manipulate resources data for complex modeling, problem solving or decision-making in the planning process, computer assistance is necessary because of the efficiency, including time, cost saving, and accuracy, that can be provided. Therefore, the conversion of inventoried data into digital form is warranted. For example, in Section 3.7.6. a composite suitability map for alignment of least disruption to existing forestry production is generated by overlaying a vegetation types map, a tree size map, and a forest stocking map. If a manual method were used, this process would require approximately one hundred man hours. Assuming $4 per hour in wages, the cost would be $400. When a computer is used, approximately 5 minutes CPU time is required, which costs approximately $35. Also, the computer can test the process many times in order to obtain the optimum answer, an option which the manual method cannot afford in either time or cost.

2) The need to use an automated method of data conversion.

Because of the vast amount of data involved in land and resources planning, manual digitizing costs much more, requires much more time, including data editing, and also provides less accuracy. A map may require hundreds of man hours to be manually digitized, while it may take only two or three hours to be automatically digitized. An automated method can provide higher accuracy and speed and a lower cost of data mapping and conversion.

3) The need to constantly and instantly revise and update inventoried data at an affordable cost.

4) The need to reduce the incidence of error.

5) The need to reproduce inventory maps at any scale, by an area defined by the designated geographic boundaries. and by any desired combination of data elements.

It is necessary to emphasize that although an ERGIS data bank alone will not offer solutions to planning problems, methodology will. Therefore, Section One of this report discusses the important issues of methodology development in detail in order to avoid misuse of the ERGIS data bank. The ERGIS data bank is a "tool" used to increase efficiency. However, it is incapable of changing the nature of input instruction, which includes the logic of planning methodology and the quality of inventoried environmental data. If the input methodology and data are erroneous, it will simply be a "garbage in and garbage out" situation in terms of results.

The above statements are primarily intended as a precaution to data bank users. On the other hand, due to the ever increasing complexity of resources data and management methods, manual processes simply involve excessive time and financial requirements. Without a computer data bank's assistance, studies will have to be simplified, and thus will result in either erroneous management policies and planning decisions, or a lack of quality planning.

In order to increase efficiency, the ERGIS data bank has built in durability, reliability, accuracy, speed, flexibility, and compatibility. All of these capabilities, as well as the function of each ERGIS subsystem, will be discussed in Section Two.

The ERGIS data bank is designed to be a statewide or regional data bank for multi-purpose manipulations such as highway corridor and electric transmission corridor selections, proposed land use planning studies, industrial siting, etc. The design of the ERGIS is not for single uses; but rather incorporates as much flexibility as possible in order to provide a wide range of services. On the other hand, flexibility cannot be incorporated without cost, and it may even reduce original software and hardware efficiency. If the ERGIS is used for only one purpose, only a portion of the system is needed. For example, if only the microcell overlay method is used with color maps as input material, the ERGIS can be greatly simplified, therefore increasing the system efficiency.

After the discussions of methodology and the ERGIS data bank, a case study is presented in Section Three which applies the ERGIS data bank to a planning methodology for extra high voltage (EHV) transmission corridor selection.

1.2. Methodological Research on Land and Resources Utilization

1.2.1. Goal of Land Use and Resources Planning

The ultimate goal of land use and resources planning is to help bring society to an ideal stage. The image of this ideal stage varies according to different philosophical findings. Harrison Brown, in The Challenge of Man's Future, concludes that in our distant future we can choose among three possible patterns of life: the first pattern is a reversion to agrarian existence; the second is a completely controlled, collectivized industrial society; the third is a free industrial society in which human beings can live in reasonable harmony with their environment (Brown, p. 204). If these are the choices, the third pattern appears most desirable. Thus, using technological skills to live in reasonable harmony with our environment is the planning goal of land and resources utilization.

Brown also points out the difficulty in achieving and maintaining the third pattern of existence:

> It is unlikely that such a pattern can ever exist for long. It certainly will be difficult to achieve, and it clearly will be difficult to maintain once it is established. Nevertheless, we have seen that man has it within his power to create such a society and to devise ways and means of perpetuating it on a stable basis. In view of the existence of this power, the possibility that the third pattern may eventually emerge cannot be ignored, although the probability of such as emergence, as judged from existing trends, may appear to be extremely low. (Brown, p. 204)

1.2.2. General Background

It is widely recognized that the knowledge and methodology of land use and resource planning are still in the embryonic stage, but the importance of this field to the entire development of society will not allow us further hesitation. To date, substantial agreement has been reached concerning a "multidisciplinary approach" to land use and resource planning. Above all, special emphasis has been placed upon establishing a methodological framework.

Land use planning is an extremely complex task, not only involving growth strategy and technology development, but also dealing with the natural environment and economic and social systems. Furthermore, it requires design skill, which utilizes psychophysiological criteria as design and construction standards in order to build up accommodations for socioeconomic activities within a given natural environment.

Detailed methodology that can be used to generate a comprehensive proposed land use plan at a practicable level is not currently available, perhaps because people have not really felt a full-scale threat by land use problems. Therefore, advocacy of land use planning by its proponents gains insufficient public support to induce Congress and governmental branches to take the major actions necessary to develop such a methodology for comprehensive planning, and to interact with and advise private sectors to ensure the fulfillment of such comprehensive planning.

As human activity and population increase, space is more precious than ever. Prudent designs can help maintain human distance at a comfortable level. To avoid negative effects of technology and to increase harmonization of living space, comprehensive planning will be required. Considering the availability of present technology, it is possible to generate a methodology of comprehensive planning. However, it will require a research effort on the scale of the space program or Project Independence, involving experts from various disciplines, years of collaborative efforts, and millions or billions of dollars. After the methodology of land and resources utilization is fully developed and standardized, it is likely that a special hardware and software data bank

system will be manufactured and dedicated to accommodate the new methodology's requirements with the highest efficiency.

However, as stated previously, a comprehensive planning method is not now available. The intent of the following sections is to discuss the framework, important issues, and major steps of developing this methodology in order to reveal the complexity of the issue and the reasons that the project for development of this methodology will be similar in magnitude to the space research program.

1.2.3. Planning Approaches

An essential task of land use planning is to generate a methodological framework upon which a proposed land use plan can be produced to serve as a guideline for future land and resource utilization. Although this sounds like a simple task, the complexity involved has delayed the research and development of land use planning methodology and has prevented the passage of any major comprehensive land use planning laws at either the federal or state levels.

Before such legislation can be enacted, it must be decided at which level of intensity planning should be imposed. Planning implies control; carried to its extreme, it means robotization, which heavily encroaches upon the individual's freedom and dignity. Without planning, however, the trend of our society would likely be a reversion to primeval agrarian existence. Lying between these two extremes, there are myriads of intensity levels of planning (i.e., control).

In general, planning can be grouped into two major approaches with regard to intensity, one termed the direct approach, the other, the indirect approach. The direct approach takes the initiative of instructing where to build, what to build and when to build; it requires in-depth knowledge of existing and future human activity and of our environment. It directs future growth and development according to the pre-planned scheme. The indirect approach tells where not to build and what not to build in order to protect the society and the environment from disasters. Further explanation of these approaches follows.

1.2.3.1. Direct Approach

The direct approach can be divided into seven major planning processes: 1) land use classification by types, 2) technological research, 3) projection of change and distribution, 4) study region delineation, 5) human activities analysis, 6) environmental inventory and analysis, and 7) interaction and synthesis. The interrelationships among these steps are presented in Diagram I. Further discussion of each step follows.

I. Land Use Classification by Types

Human activities--work and non-work content--involving both land and water have formed the patterns of land use which can be grouped into two categories: 1) natural resource-based land use, involving the direct utilization of natural resources, such as mining, primary manufacturing, agriculture, forestry and natural resource-based recreation, and 2) cultural-based land use, involving the utilization of land or water for cultural activities (although utilization of natural resources may sometimes be indirectly related), such as shopping, cultural-based recreation and institutional activities.

Natural resource-based land use can be further divided into two subgroups: 1) those involving renewable resources (from both land and water), including food, fiber and forest products, and 2) those involving exhaustible resources (from both land and water), including mineral and certain energy resources.

Conventional land use classifications used in planning are these:

1) Industrial - often further divided into light, medium and heavy industrial land uses without clearly defining each sub-category.

2) Commercial - further divided into retail and wholesale (or warehouse), or aggregated and isolated.

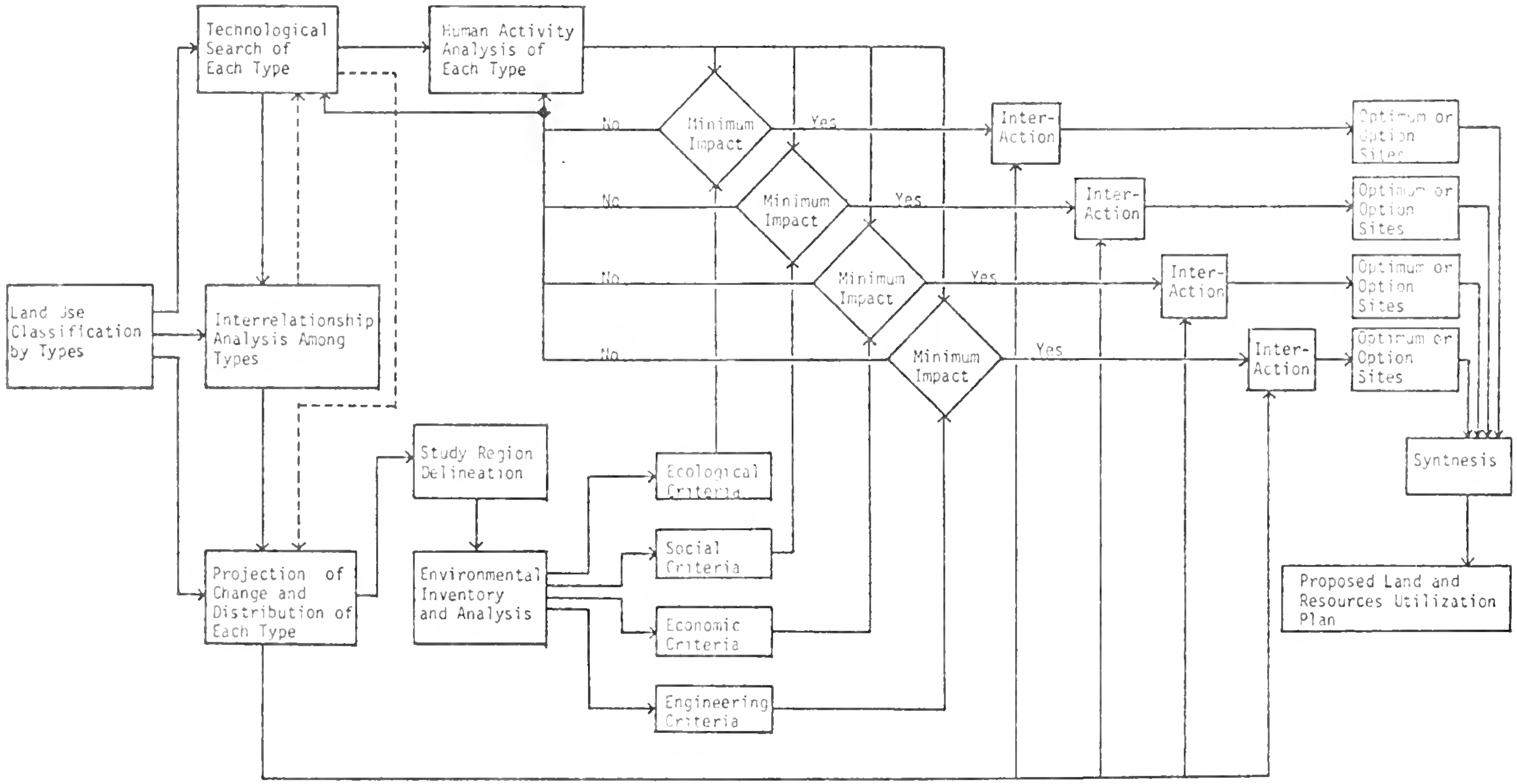

Land Use Classification by Types
Technological Search of Each Type
Interrelationship Analysis Among Types
Projection of Change and Distribution of Each Type
Human Activity Analysis of Each Type
Study Region Delineation
Environmental Inventory and Analysis
Ecological Criteria
Social Criteria
Economic Criteria
Engineering Criteria
No
Minimum Impact
Yes
No
Minimum Impact
Yes
No
Minimum Impact
Yes
No
Minimum Impact
Yes
Inter-Action
Inter-Action
Inter-Action
Inter-Action
Optimum or Option Sites
Optimum or Option Sites
Optimum or Option Sites
Optimum or Option Sites
Synthesis
Proposed Land and Resources Utilization Plan

DIAGRAM I

3) Residential - further divided into single family and multi-family residences or divided according to density.

4) Agricultural - further divided into cropland, pasture, rangeland, etc.

5) Public and Quasi-Public (or Institutional) - further divided into governmental use, educational use, hospital, church, etc.

6) Recreational - including parks, campgrounds, water-related activities, historic sites, points-of-interest, etc.

7) Transportation and Utility-related - including highways, railroads, airports, electric transmission lines, pipelines, power plant sites, refinery sites, etc.

8) Others

This conventional classification is insufficient for direct approach land use planning because some of its categories are too broad to be used for predicting future growth (growth-related issues will be discussed later) which determines future land use patterns. Taking industrial land use as an example, certain industrial development, because of its magnitude, often forms new urban, residential and commercial areas.

Classification of land use types is also related to the planning level used. Because of the content and scope of the work involved, land use planning should be executed at three different levels: 1) national level, 2) state level, and 3) local level.

II. Technological Research

The historical change in land use patterns actually reflects the history of technological change. Prehistoric man lived as a natural animal; land use patterns at that time were similar to natural patterns. The development of agricultural tools resulted in the change of timber land and grassland into farmland. Industrialization accelerated the development of urban and metropolitan areas. Each technological innovation initiates land use changes.

The change of our transportation system from railroad to highway to freeway has resulted in drastic changes in land use. In the future, the materialization of a mass transit system or any new transportation devices will also change present transportational land use patterns.

Due to the resources required, modern technological research and development (R and D) usually become the responsibility of the federal government. Major industry may have the resources required for such R and D, but, because industry is motivated for profit earning, such R and D may not be oriented for societal welfare.

The federal government has the responsibility not only for technological R and D, but also for the direction of technological change. For example, use of the automobile as a transportation tool has resulted in approximately 1.7 million acres of land being taken out of farm production or other uses (freeway system-related only), and approximately 50,000 deaths per year, and has become a major source of air pollution. If the costs involved in using the automobile should be judged unacceptable by society, what type of transportational tool should be developed, and how should the transition be made in order to minimize overall impacts?

Another example is energy-related technological development. Potential and real energy presents itself in various forms, such as gas, oil and electricity. Conventionally, electricity has been generated from a hydro plant, coal-fired plant, gas/oil turbine plant or nuclear fission plant. Further development of nuclear breeder reactors, geothermal plants, solar

power, magnetohydrodynamics (MHD), fusion power and other alternate sources is being investigated. The decision to depend heavily on certain technological methods will inevitably result in changes of land use patterns. Some regions may have a drastic change; others may not. All of these variables will depend upon such criteria as availability of natural resources, existing land use patterns and existing social and economic structures.

III. Projection of Change and Distribution

Change in human activity due to growth, a decrease in the intensity of human activity, or generation of new activities will result in changes of land use patterns. In order to develop a proposed land use plan, accurate projection of these changes is essential. Before making such projections, it is important to first define the interrelationship among activities, including such factors as which resources must be made available to other activities in order to sustain each activity. This interrelationship depends on the technological development of each activity.

Projection and guidance of change of all human activities should be made first at the national level because:

1) In order to guide the growth change for the best interest of the nation, a national policy is required. A state or regional policy may be for the best interest of the state or region, but may conflict with the interest of the nation as a whole. On the other hand, without first clearly defining the national policy, the efforts of state or local planning could often be rendered useless or ineffective.

2) Both social and economic structures, at the national level, have a characteristic of being "closed," while at the state or regional level they have been "open" in character (i.e., at the national level, more accurate control and projection can be made). Thereafter inter-state and inter-region exchange can be established.

The factors that affect the growth or decline of certain activities are many, including population and economic changes. Various indicators have been used to predict these changes. Also, governmental policy plans an important role. For example, mandatory energy conservation policy, in the long run, may drastically reduce the energy growth rate, resulting in a much reduced rate of installation of energy generation or conversion plants.

After the rate of change has been projected for each activity, especially natural resources-based land using activities, it is necessary to distribute this change to different geographic locations of the state or region and to available resources. For example, after the projection of energy consumption by major sources has been made, any change of the growth in one source will affect the other sources. If, by the year 2000, the national energy consumption reaches 175 quadrillion BTU, distribution of this consumption to available major sources such as coal, petroleum, natural gas, nuclear power, hydro power and geothermal will require an in-depth study at the national level. If coal is to assume the partial burden to supply the demand, a decision must then be made about the distribution of the required coal between eastern coal (Appalachian region) and western coal (Fort Union Basin). If western coal is to be used to supply 5.5 quadrillion BTU at the year 2000, approximately 10 square miles of land per year will be stripped, and many additional square miles will be needed for installation of conversion plants; thousands of square miles will be affected. As this example indicates, a decision made at the national level can have an efficacious impact on local land use planning.

IV. Study Region Delineation

After the distribution of the growth of each human activity has been decided upon for the requisite number of future years, a homogeneous region can be defined based on this distribution. This region can be either interstate or intrastate, depending upon the homogeneous characteristics of the natural and cultural environment. Existing political jurisdiction should be considered carefully when delineating the boundary of the region. Unless absolutely necessary, establishment of an interstate region should be avoided. If it becomes necessary to create one, an interstate organization should be established

to take the administrative responsibility. The delineated region will be the unit study area for the proposed land use plan.

V. Human Activities Analysis

As science continues to develop, population increases and materials build up, human activities become more and more complicated, and in turn, conflict with each other. Activities which misuse land and activities without adequate control, although occupying only a small tract of land, may trigger a series of interlocked reactions and imperil or damage other activities. Thus, it is necessary to have constraints on all activities in order to protect one from the other. If industrialization does co-exist harmoniously with the environment, a higher level of industrialization does not necessarily mean more constraints on individual and societal freedom and more complex planning.

After a study area has been defined, human activities likely to occur within the study region should be analyzed. Before the intrinsic suitability of the environment can be determined for different human activities, it is essential to know the criteria required to establish such human activities. Four sets of criteria have been identified: 1) construction requirements, 2) material input, 3) material output, and 4) amenity requirements.

It would be impractical to consider only the requirements to erect or install human activities on the land because, more often than not, particular human activities, especially industrial activities, have an influence periphery much larger than the area on which they are located. Thus, besides construction requirements, we need to identify factors that have an effect on surrounding and distant environments. The natural environment must be considered as an integral unit and human activity as another integral unit. During the processes of interaction, if the materials taken from the natural environment for human activities are returned to the natural environment in the same place, quality and quantity, or at a level of loss whereby the quality and quantity can be restored by natural process itself, or if the rate of loss can be absorbed without deleterious effects on a healthy environment, then the natural environment will be self-perpetuating and will offer ample opportunities and amenities for human uses. If this

pattern of equilibrium breaks down, the environment deteriorates. This process of deterioration has been, in fact, occurring in our environment for the last few decades.

Certain natural resources utilized by human beings retain their original form and can be used again. For example, most water withdrawn from a watercourse is returned; therefore, total water withdrawn (along the watercourse) may exceed river flow many times over (Hamilton, p. 6). However, the quality of water returned after industrial, agricultural or sanitary use is usually downgraded. As a result, many rivers are polluted and dying.

Another example is ground water. Most ground water taken up for human usage is returned, not to the aquifer, but to the nearby river, lake or seashore. One possible consequence of aquifer depletion would be the formation of a cone depression of the piezomatic surface, perhaps followed by the sinking of a city. The nearby phreatophytic plant community is also affected. Of course, this phenomenon appears more severely in arid and sub-arid regions.

Events such as these involve issues beyond the intrinsic suitability of land for human uses; they bring to question the necessity of certain human activities. That is why land use planning demands the analysis of human activities.

Matrix I, using as a example a 700 megawatt (MW) coal-fired power plant, offers some idea of how a human activity analysis matrix can be constructed. The content and methodology of human activity analysis may never reach perfection due to constant changes in the technological content of human activities. However, its use can at least protect the quality of our environment from the dangers inherent in existing land uses and provide a regulatory tool for proposed land use. Although our technology is imperfect, with contemporary knowledge we are potentially capable of balancing the input and output of any activity. McHarg has pleaded for governmental protection through regulations or laws. In Design with Nature he states that:

MATRIX I*

HUMAN ACTIVITY TYPES	CONSTRUCTION REQUIREMENT	INPUT			OUTPUT			AMENITY REQUIREMENTS	
		MATERIAL TYPES	SOURCES	QUANTITY and QUALITY	MATERIAL TYPES	DESTINATION	QUANTITY and QUALITY	NATURAL	CULTURAL
A 700 M W coal fired electric generating plant	(1) Foundation requirement of (a) power plant (b) ash pond, and (c) water storage pond. (2) Construction labor force: construction period - 3 to 4 years. Peak labor force - more than 1600. Detailed labor force by major crafts & time schedule - omit.	Coal	Nearby coal field	Coal supply: 903,376 lb/hr or 3,956,787 ton/yr at 100% load factor or 3,165,430 ton/yr at 80% load factor Coal Quality (average coal content): Moisture 25.65% Ash 10.16% Volatile Matter 29.7% Fixed Carbon 34.47% BTU/lb 8383 Sulfur .89%	Exhauster Gas	Atmosphere	SO_2 9,583 lb/hr or 41,974 ton/yr at 100% load factor 33,578 ton/yr at 80% load factor Water Vapor 641,394 lb/hr NO. 5,301 lb/hr Particulate 367 lb/hr F 2.35 lb/hr Hg .121 lb/hr Pb .336 lb/hr Ra^{226} $4.6x10^{-6}$ Ci/hr Etc.	Omit	Omit
		Air	Atmosphere	Air Supply 7,055,222 lb/hr	Ash from Boiler & Economizer Hoppers	Ash Pond	18,350 lb/hr or 80,373 ton/yr at 100% load factor		

MATRIX I (Continued -1)

HUMAN ACTIVITY TYPES	CONSTRUCTION REQUIREMENT	INPUT			OUTPUT			AMENITY REQUIREMENTS	
		MATERIAL TYPES	SOURCES	QUANTITY and QUALITY	MATERIAL TYPES	DESTINATION	QUANTITY and QUALITY	NATURAL	CULTURAL
				air quality: typical non-polluted rural air			64,298 ton/yr at 80% load factor		
		water	Nearby lake	max. withdrawal rate: 15,780 GPM Quality (mean value only): pH - 8.20 Specific Conductance (umhos/cm @ 25° C) 579 Calculated Dissolved Solids 422 μg/l Dissolved Oxygen 10.4 μg/l Biological Oxygen Demand 2.8 μg/l Fecal Coliform 35 (counts/ 100 ml) Total Hardness CaCo 188 μg/l	Fly ash from scrubber	ash pond	73,032 lb/hr		
					SO_2 from scrubber	ash pond	6,388 lb/hr		

MATRIX I (Continued -2)

HUMAN ACTIVITY TYPES	CONSTRUCTION REQUIREMENT	INPUT			OUTPUT			AMENITY REQUIREMENTS	
		MATERIAL TYPES	SOURCES	QUANTITY and QUALITY	MATERIAL TYPES	DESTINATION	QUANTITY and QUALITY	NATURAL	CULTURAL
				Alkalinity $CaCo_3$ 123 μg/l Laboratory Turbidity 95 μg/l Total Suspended Solids 279 μg/l Calcium 43.1 μg/l Mercury <0.001 μg/l Etc.					
		Chemical Materials Including: Ca HCO_3 Mg CO_2 Na SiO_2 NH_3 PO_4 SO_4 Cl_2 Cl Alum Suspended Solids Etc.		Detailed Chemical Materials flow in LBS/HR according to various locations - omit					

* This matrix offers only an overview.

> . . . there are few deterrents to arrest the dumping of poisons into the sources of public water supply or their injection into ground water sources. You are clearly protected from assault by fist, knife, or gun, but not from the equally dangerous threats of hydrocarbons, lead, nitrous oxides, ozone or carbon monoxide in the atmosphere. There is no protection from the assaults of noise, glare and stress . . .

Again, it is extremely important to emphasize that designing a human activity with both qualitatively and quantitatively balanced input and output is more valuable than using siting criteria for human activities to minimize the impact. If pollution-free human activities can be designed, it will not be necessary to worry about environmental deterioration. Instead, it will be possible to concentrate on utilizing psychophysiological skill to improve the amenity requirements for each activity and human activities as a whole.

VI. Environmental Inventory and Analysis

After all human activities within the study area have been analyzed, environmental criteria can be established to select the optimum area for each activity. Environmental criteria can be divided into four major groups: 1) natural ecological system-related criteria, 2) social system-related criteria, 3) economic system-related criteria, and 4) engineering-related criteria. Geographic areas meeting the criteria for one group may not fulfill the criteria for other groups because conflicts exist among these groups. Further discussion of the criteria related to these four groups follows.

(1) Natural Ecological System-Related

As mentioned in Section V, if input materials of human activities can be balanced with output materials, environmental degradation can be avoided. However, for present activities, especially major industrial activities such as smelters, refineries and power plants, this balance has not yet been reached, although not because we are incapable of achieving it. In light of the present non-existence of input-output balance for some human activities, the follow-

ing discussions include the siting criteria necessary to minimize the impact.

(A) Dynamic Natural Cycles Analysis

In order for a human activity to become a healthy part of the earth, natural processes or cycles are used to interact with input and output materials analysis in order to find optimum locations with minimized impact and maximized benefit and also to find if these locations are in an equilibrium stage with their surrounding environment. If not, a check-back loop, as shown in Diagram I, is called for in the design improvement of such activities. Until the equilibrium is reached, there would be no advance to the next step.

The cycles mentioned above are the hydrological cycle, the biomass cycle, the solar energy cycle, the air cycle and the soil particle cycle. To illustrate these cycles and to examine and minimize the impact placed upon the natural environment by input or output materials, two examples are given:

Example 1

The total amount of water withdrawn from a ground aquifer should be equal to or less than the total amount of water that enters the aquifer. The total amount of water withdrawn from an aquifer is equal to the sum of the following factors: (a) the discharge from the aquifer to a river, lake, wetland or ocean (providing the piezometric surface is above the river, lake, wetland or ocean surface); (b) the water taken up by plant root systems; (c) the water evaporated from the ground aquifer (through capillaries rising to the earth's surface); and (d) the water utilized for human activities. The total amount of water recharging the ground aquifer is equal to the sum of: (a) the amount of precipitation that infiltrates, percolates and reaches the aquifer; (b) the discharge water from a lake, river or wetland that reaches the ground aquifer; and (c) the discharge water from human activities that reaches the ground aquifer.

If the water withdrawn from the aquifer cannot be balanced by natural restoration, it is necessary to either cut back the amount withdrawn or replenish the aquifer with the amount necessary to offset the

deficit. The quality of the replenishing water is another important consideration. If this water is not of the same quality as the natural aquifer, it must be determined whether the purification process furnished by those known soil and geological types can purify the replensihed water. If not, the low quality replenished water may not be within the allowable range to maintain a healthy environment and normal natural processes. A quantitative and qualitative hydrological cycle study can furnish the answers to these questions.

Example 2

In agricultural and conservation activities, organisms such as insects and predators are often removed or introduced. Before introducing or removing organisms, it is essential to know their biomass cycle or food chain path so the kind of mistake once made with the coyote and jack rabbit will be avoided (Graham 1944, p. 213). By applying knowledge of the biomass cycle, it is possible to maintain a natural community in a successional stage most profitable to human beings. This is called arresting succession (Graham 1944, p. 46) or anthropogenic climax (Firey, p. 25).

(B) Static Natural Environmental Structure Analysis

In order to accomplish the quantification and qualification of natural cycles, static natural environmental data are required. Major strata of the static natural environment include micro-climate, vegetation, wildlife, soil, hydrology, geology and physiography. For each stratum, areas of homogeneous patterns, such as micro-climate zones, soil types and vegetation communities, are inventoried. The level of homogeneity is determined on a relative basis.

(2) Social System-Related

Social system-related criteria for site selection include the existing social structure and social service system,including schools, hospitals, commercial services, housing, transportation, recreation facilities, sewage, and police and fire protection. In general, the social structure of an urbanized area is more diversified than that of a rural area; therefore, social change caused by construction and operation of new activities is less noticeable and more acceptable. Also, an urbanized area has a larger

capacity to provide the social services needed during construction and operation of new activities.

Public opinion reflects the public's reaction toward the social change caused by the installation of new activities. It is an extremely dynamic process, since the public's opinion may change from time to time and place to place under various conditions. To educate the public, to be educated by the public, and to incorporate public opinion into the decision-making process constitute a fundamental of democracy.

(3) Economic System-Related

Economic system-related criteria include the existing local economic structure, i.e., the local economic base, existing taxation structure and governmental expenditure. In general, a more urbanized area has greater economic diversity and less vulnerability to economic fluctuation due to changes in certain economic bases. The taxation structure reflects the sources of government expenditures in relation to economic structure. Taxation can also be used as governmental policy in guiding economic development.

Single industrial developments can reach a magnitude that causes insurmountable impacts on local economic and social systems. Taxes generated from such developments cannot be received in time to be used to relieve such impacts. Therefore, it is necessary to have an impact relief fund available in advance, such as that recently established in Montana, to be used to minimize the economic and social impacts on local communities and to maximize those communities' ability to absorb the economic benefit.

(4) Engineering-Related

Engineering-related criteria include site criteria, such as fundation requirements, and also the cost to the developer, including labor, raw material availability and marketing.

VII. Interaction and Synthesis

After analysis of human activity and area environment, a matrix can be formed, with human activity characteristics on the vertical axis and environmental criteria on the horizontal axis, in order to examine the study area's environment suitability for each human activity. An optimum site can be defined according to compatibility with each of the four groups of criteria discussed in Section VI for each human activity.

Before further discussion, it is necessary to consider the importance of taking mitigating measures. Land use planning cannot be made a single-directional process. This is the reason that the checkback loop has been used frequently in the methodological diagram. Installation and operation of certain human activities have both beneficial and negative impacts on the environment, but, on the other hand, the environment also has certain constraints on human activity. Both human activity characteristics and the environment can be modified in order to minimize the overall negative impact and maximize positive gain. These modifications of human activity, such as the change of the design specification of pollution abatement devices and the change of taxation laws, are called mitigating measures.

As mentioned before, for each activity, an optimum site(s) can be delineated under ecological, social, economic and engineering criteria. It is important to note that, if the characteristics of activities or the policy used to define the tolerance level of environmental impact is changed, the optimum site(s) delineated will also change. Therefore, and proposed land use plan will be subject to modification.

Because the ecological, social, economic and engineering optimum use of land and resources can rarely be achieved simultaneously due to the conflicts which exist among those four groups of criteria, the proper use of land and resources must be determined by the subjective judgment of human beings. In order to achieve a particular purpose, land and resources are usually conserved or developed for use at the expense of other potential uses. Thus, as many options as possible should be considered. A range of possible modifications should be generated

for different levels of intrinsic suitabilities rather than allowing a single criterion to be the sole determining factor for land and resources utilization.

The generation of a range of possible modifications can be accomplished as indicated below for natural ecological criteria:

Generally speaking, any natural environment can be grouped into one of three major types according to its intrinsic suitability for human activities:

1) In a very few cases, the natural environment in its wilderness condition can offer full intrinsic suitability for such human uses as conservation and certain recreations.

2) Most of the time, the natural environment requires modification or management to achieve maximum suitability for human activities. The level of modification determines the level of uses, such as various agricultural and urban uses. G. Angus Hills suggested further division of this type into three major group: a) modification required at the individual level, b) modification required at the corporation or local community level, c) modification required at the state or federal level or by combined task forces. Apparently the division of these three sub-groups is based upon the political and organizational system, which implies different levels of economic involvement.

3) There are certain areas that are intrinsically inhospitable to human uses, and careless construction in these areas can result in the loss of human lives; such areas include earthquake zones, 10 or 100 year floodplains, and hurricane paths. Since contemporary technology cannot stop an earthquake or hurricane, it is wise to avoid an area susceptible to natural disasters or to develop a means of protection which can secure man from such natural calamities. An area requiring less modification obviously offers a higher intrinsic suitability.

This system of classification does not suggest a rigid system for dividing and grouping the natural environment. For example, the floodplain is grouped in low intrinsic suitability (group (3)). However, if a levee or other type of protection can be offered, this floodplain may then be grouped in 2 (b) or 2 (c). Thus, for each land unit or water area, a chart can be constructed to indicate the diverse used which are supported by different modifications.

The optimum ecological use of land and resources is defined by this statement: "the intervention of human activities will not divert or fix the natural trend of organic and physical processes from or below their ecological climax." If a consistent and prolonged type of human activity has stabilized a natural process before it reaches its ecological climax, it is defined as an anthropogenic climax (Firey, p. 25). As a result of the above classification process for each land and water unit, a list of single or multiple land uses is generated corresponding to the required modification and different levels of natural intrinsic suitabilities.

The above example dealing with mitigating measures is considered in relation to the ecological environment only. The same method can be applied to social, economic and engineering groups. A final proposed land and resources utilization plan is a result of interaction among ecological, social, economic and engineering options. Although, as stated before, the ecological, social, economic and engineering optimum use of land and resources can rarely be achieved simultaneously, the possibility should not be ruled out. Besides, these optima can nonetheless serve as ". . . ideal standards from which a resource system departs at the cost of predictable consequences and canons of what ought to be but can never be." (Firey, p. 252) When this total optimum is impossible, a trade-off between ecological, social, economic and engineering options must be made. During the process of deciding on trade-offs, various mitigating measures plan a role of the utmost importance, although the final decision is a policy-related issue. Because of this, planning methodology should incorporate flexibility, and proposed land and resources utilization plans should be periodically updated and modified when necessary.

1.2.3.2. Indirect Approach

The indirect approach to land use and resource planning has been exercised historically up to the present. Many laws are written to protect certain critical resources by means of limiting other human activities; examples are the laws that govern wilderness areas, wildlife reservations and floodplains. Even air and water quality standards are written taking this indirect approach, delineating what not to build and where not to build. The indirect approach has been carried out on a case by case basis and is still the best available tool to protect against adverse encroachment before the materialization of the direct approach and comprehensive planning.

From the discussion of direct approach planning methodology, it is apparent that step 6, Environmental Inventory and Analysis, and step 7, Interaction and Synthesis, will require geo-information computer data bank assistance due to their complexity and efficiency requirements. Inventoried environmental data must be stored in uniform digital form for interaction and synthesis, and also for data output and display. The most commonly used interaction and synthesis method is the overlay technique; i.e., after the geo-information has been evaluated for human activities suitability in a spatial-related manner, the resultant suitability maps will be combined according to the scheme predetermined in the methodology. This technique is used in the case study presented in Section Three.

Storage of geo-information data in digital form requires an input system and a storage system. Data interaction and synthesis relate to data manipulation. In order to display the stored data and the results of data manipulation in the desired manner, an output and retrieval system is necessary. Therefore, an Environmental Resource Geo-Information System data bank should comprise input, storage, output and manipulation subsystems. Before discussing the developmental history of the resources management data bank and ERGIS subsystems, it should be re-emphasized that the function of the ERGIS data manipulation component is based upon the methodology of land and resources utilization, and also that the functions of data input, storage and retrieval components depend upon the requirements of data manipulation. The above described functional characteristics make ERGIS different from automated cartographic systems and certain other computer data banks.

2.1. Definitions

The land and resources management data bank is a newly established area of development, and universally accepted definitions of terminology are nonexistent. Therefore, certain terms that will be used in this study are defined below.

1) Line, Descriptor and Descriptor Map

Lines are used to delineate the boundaries of the inventoried resources on the maps, such as the delineation of highways, the contour lines, and the boundaries of vegetation and soil types. The descriptor is the description used on the map to indicate the types or characters of the inventoried resources. Examples are shown in Figures 1 and 2. The maps shown in Figures 1 and 2 are called descriptor maps.

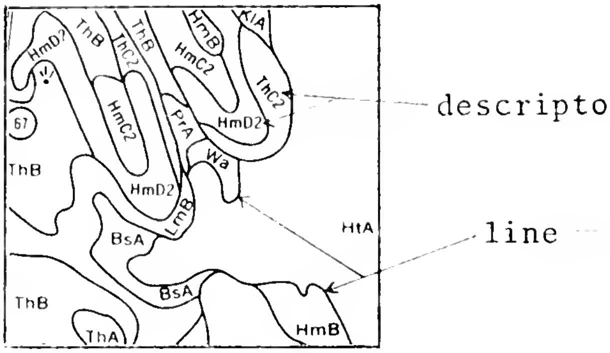


Figure 1

Soil Type Map

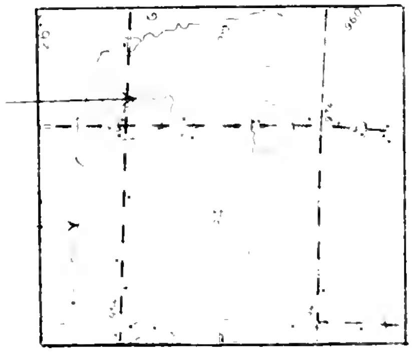


Figure 2

Topo Map

2) Polygon System

A polygon represents a closed area or plane bounded by line segment(s). A line segment is a line defined by intersection points (i.e., the beginning and end points of this line segment) or a closed circle. Regular types of polygons such as polygon 1 and polygon 4 (indicated as Py1 & Py4) are shown in Figure 3. Center-void polygons are the shaded areas shown in Figure 4.

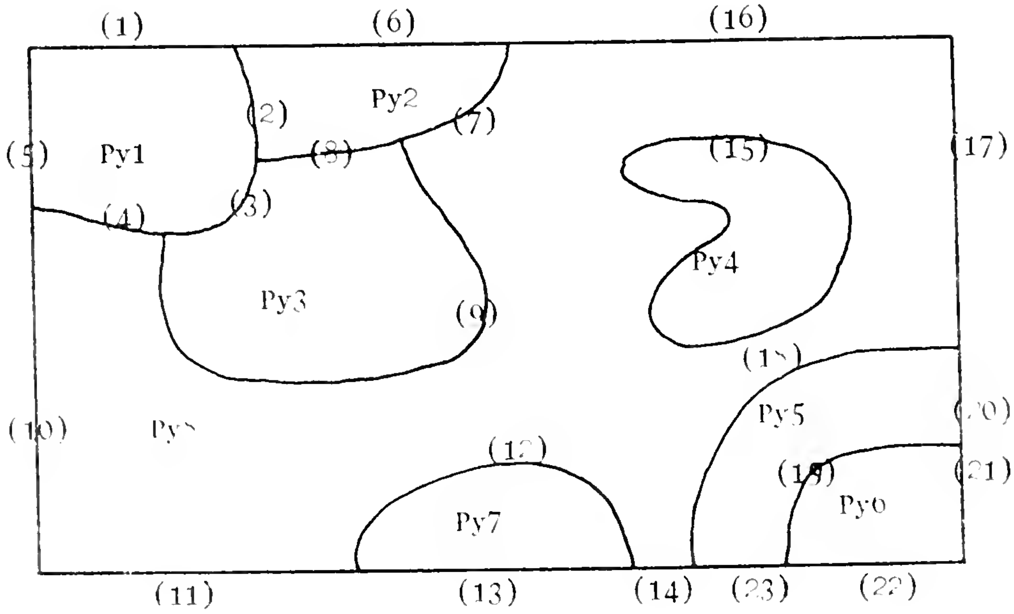


Figure 3

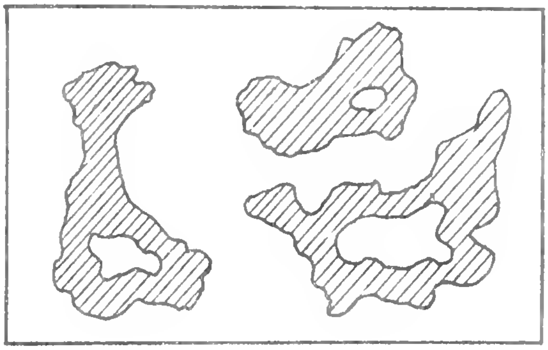


Figure 4

Polygon format is usually presented in the following manner: Polygon 1 (Py1) is comprised of line segments 1, 2, 3, 4, and 5. Abbreviation L1 represents line segment 1 indicated as (1) in Figure 3 and so on with L2, L3, L4, and L5. (In this case, the corner points of the border lines are also defined as intersection points.)

FORMAT

Py 1 is comprised of L1, L2, L3, L4, L5
Py 2 is comprised of L2, L6, L7, L8
Py 3 is comprised of L3, L8, L9
Py 4 is comprised of L15
Py 5 is comprised of L18, L20, L19, L23
Py 6 is comprised of L19, L21, L22
Py 7 is comprised of L12, L13
Py 8 is comprised of L4, L9, L7, L16, L17, L18, L14, L12, L11, L10, L15

Also:

L1 is comprised of point X_{11} Y_{11}, point X_{12} Y_{12}, point X_{13} Y_{13},...Point X_{1n} Y_{1n}. In this series, X_{11} Y_{11} are the X and Y coordinates of Point 1, X_{12} Y_{12} are the X and Y coordinates of Point 2 and so forth. The first subscript number indentifies the line segment, i.e., all points of L1 will use 1 as their first subscript number. The second subscript number represents the sequence of the point on a line segment. Figure 5 illustrates the format of describing line segments.

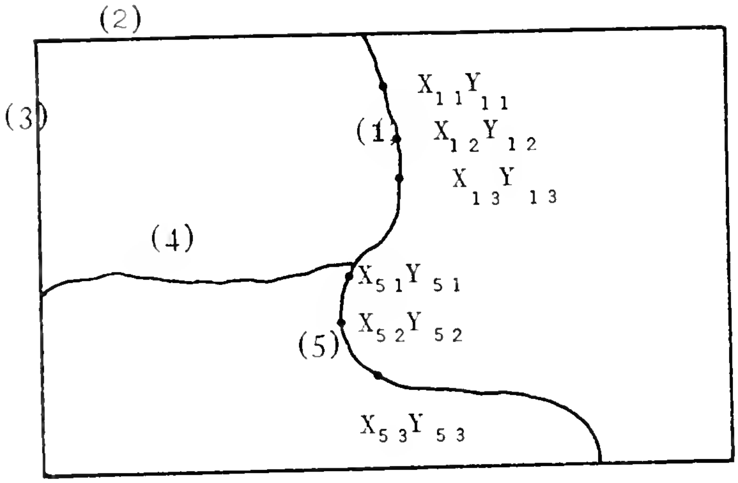


Figure 5

FROMAT

L1 is comprised of $X_{11}Y_{11}$, $X_{12}Y_{12}$, $X_{13}Y_{13}\ldots\ldots X_{1n}Y_{1n}$
L2 is comprised of $X_{21}Y_{21}$, $X_{22}Y_{22}$, $X_{23}Y_{23}\ldots\ldots X_{2n}Y_{2n}$
L3 is comprised of $X_{31}Y_{31}$, $X_{32}Y_{32}$, $X_{33}Y_{33}\ldots\ldots X_{3n}Y_{3n}$

$\vdots \qquad \vdots \qquad \vdots \qquad \vdots$

Lm is comprised of $X_{m_1}Y_{m_1}$, $X_{m_2}Y_{m_2}$, $X_{m_3}Y_{m_3}\ldots\ldots X_{mn}Y_{mn}$

In the case of a closed circle without other intersection line or lines, the beginning and the ending point of this circle must be the same point (example: polygon 4 of Figure 3).

In the above example, a line segment is defined by connecting a series of points. On the other hand, a line segment can also be defined by a series of vectors.

The formats given in the above examples are rudimentary. They can and will be changed drastically in order to increase storage efficiency.

3) Grid System

A grid system is a format used to present the land use and resources data by uniform modular cells. These modular cells can be squares or parallelograms (see Figure 6), or any other uniform shape such as hexagons and octagons, if necessary. However, the square shaped cell is used most commonly.

Modular Cell
in Square Shape

Modular Cell
in Rectangle Shape

Modular Cell
in Diamond Shape

Modular Cell
in Parallelogram Shape

Figure 6

The data of a modular cell can be presented either in percentages, which is termed percentile cell format, or represented by the dominant datum only, which is termed dominant cell format. Within a percentile cell, each land use and resources datum is presented according to the percentage of a cell it occupies. For example, cell 2020 is spatially occupied 20% by western ponderosa pine, 30% by Douglas fir, and 50% by lodgepole pine. In the dominant cell format, cell 2020 is represented by lodgepole pine, which is spatially dominant (50%) over the entire cell.

According to the cell size, the grid system can be represented by either regular cell size (i.e., macro-cell) or micro-cell size. The difference between the two sizes is based upon the scale and the actual ground size represented by each cell. The dividing standard is rather arbitrary, but the micro-cell is defined as that cell size smaller than or equal to $\frac{1}{2500}$ square inch. (This size is related to the size and scale of the input material.) Any larger amount is a regular cell. For example, if input material with a scale of one inch equal to one mile is used, a cell size smaller than or equal to 0.250 acres is called a micro-cell.

In general, micro-cells of a regional and statewide data bank will have to utilize an automated data input machine because a manual input method would be too time-consuming and costly.

4) Overlay Technique

The overlay technique is a method used to combine various maps by superimposing one on top of another. For example, map 1 of Figure 7 is overlaid on top of map 2, and, as a result of combining the information presented by both maps, map 3 is generated (see Figure 7). The overlay technique can be applied to both the polygon system and the grid system. The most important criterion is that all maps must be at the same scale.

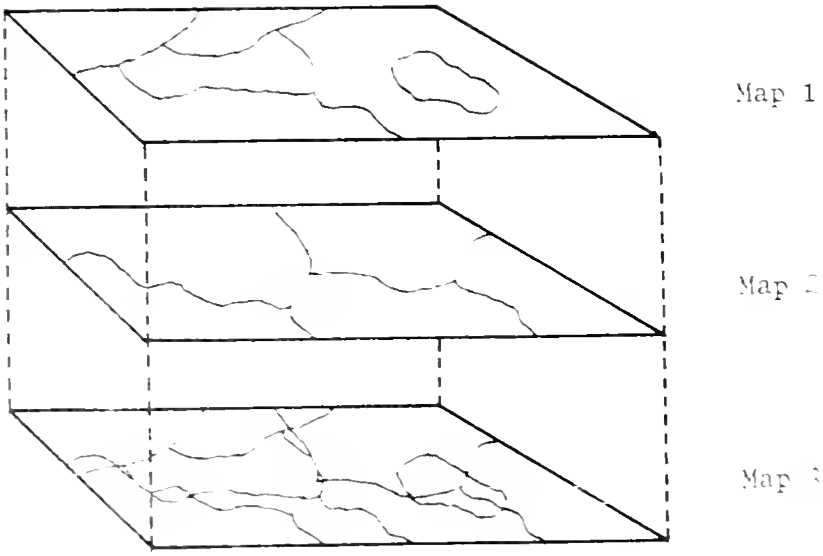


Figure 7

2.2. Developmental History of the Land and Resources Management Data Bank

During the last 15 to 20 years, the scientific community as a whole has not turned specific attention to the application of computer technology to land and resources management. The developmental history of this type of data bank has been sporadic at best, and is therefore impossible to trace with precision.

The development of the land and resources management data bank is still in its embryonic stage, following and/or paralleling two major developments: computer technology and automated cartographic technology.

Due to the availability of the I/O unit (line printer) at an early stage, the grid system was created by taking advantage of the matrix print-out. This was followed by the availability of the linear plotter and manual digitizer which made the polygon system possible. The development of this equipment is described as follows:

> Drafting and digitization units were well known even in 1960, particularly in the areas of aircraft and missile analysis and in the development of some automatic machine tools...
>
> Before and during the early 1960's, the wide use of small, general-purpose computers was unknown. However, the larger digital computer was coming more and more into use, and this set the stage for a major advance by the Calcomp Corporation when they made their purely digital incremental plotter. Calcomp not only developed the device itself, but also realized the need to provide adequate software support to prospective users.
>
> ...In the period from 1962 to 1964, a major development was the "free pencil" digitizer built by D-mac in Scotland and the Rand Corporation in the U.S.A. For the first time, the digitization of

> cartographic line tracing became viable. (Geographical Data Handling, Volume 2, p. 637)

Manual digitizers are impractical for regional and statewide data banks because of the man power required to manually digitize and edit land and resource inventory maps. Therefore, the automated digitizer has become the focal point of research efforts in recent years. Although the simple scanning unit has existed for many years, the one early unit that has been developed solely for automated map digitization is the IBM Experimental Scanner/plotter. Other manufacturers of automated digitizers are listed in Appendix I .

The above discussion has related to hardware only, while the following discussion is of various existing land and resources management data banks. It should be noted that the list is only partial.

1) NARIS

NARIS (Natural Resources Information System) was developed at the Center for Advanced Computation of the University of Illinois at Champaign-Urbana in collaboration with the Northeast Illinois Natural Resource Service Center in Lisle, Illinois, and the Northeastern Illinois Planning Commission in Chicago.

NARIS is designed for natural resources management and contains data for portions of eight counties in northeast Illinois. NARIS uses a grid system with dominant type cells that are each 40 acres in size. It also uses townships, sections and quarter-quarter sections as the coordinate system for the grid. All resources data including geology, land use, forestry, soil and water are manually coded for each dominant cell. An overlay technique is used for data manipulation.

2). LUNR

The LUNR (Land Use and Natural Resources inventory) system was developed by the Center for Aerial Photographic Studies at Cornell University in collaboration with the Laboratory for Computer Graphics of Harvard University for the New York State Office

of Planning Coordination. The purpose of establishing LUNR is to create the data base from which potential outdoor recreation sites can be indentified in New York. Further description of the LUNR system is as follows:

> Using photography flown during the springs of 1967 and 1968 at a scale of one inch to 2,000 feet, the Cornell Center transposed land use and natural resources information, as interpreted, onto overlays of USGS 7 1/2' series topographic quadrangles. A Universal Transverse Mercator grid was overlayed with a cell size of one kilometer square (1 km^2). Approximately 140,000 cells cover the entire state. A classification system of 50 land use areas and 70 items of point data was set up...
>
> ...The data shown for each grid cell fell into four categories: percent of area in each use, which could be expressed in hectars, types of specialized land uses, length of certain uses and the number of times a selected use occurs.
>
> These data were recorded by the kilometer cells on electronic data processing (EPD) cards which were merged into a direct access disc listing the data by cell, political subdivision and other referencing units. (New York State SCORP Technical Paper No. 6, p-3)

3) MLIS

MLIS (Minnesota Land Information System) was developed by the Center for Urban and Regional Affairs, University of Minnesota and was initiated and funded by the Minnesota State Planning Agency. The MLIS is used as an administrative tool to keep transaction records on all public lands and is also used as a planning and management tool. All data for MLIS are recorded manually by 40-acre parcels and government lots. A federal land survey system (i.e., township, section, quarter-quarter section) is used as the coordinate system for the grid. The 40-acre cells are recorded in dominant type.

4) MAGI

The MAGI (Maryland Automatic Geographic Information) system was developed by Environmental Systems Research Institute, Redlands, California, and sponsored by the Maryland Department of State Planning. The purpose of the MAGI system is to provide Maryland with a statewide resources inventory data bank. Information concerning soil, geology, aquifer recharge areas, mineral resources, slope, unique and endangered natural features, scenic areas, etc., is stored in a grid system. The dominant, secondary and tertiary data of each cell are recorded. The encoding method is either a manual process or utilization of a manual digitizer. Software is provided to convert the manual digitizer polygon into the grid system. The cell size is 2000' x 2000' or approximately 91.8 acres. The State Plane Coordinate System is also used.

5) SYMAP

SYMAP was originally written in 1963 under the direction of Howard Fisher at Northwestern University and is currently maintained by the Laboratory for Computer Graphics of Harvard University.

6) ACG/DIME

The ACG/DIME (Address Coding Guide/Dual Independent Map Encoding) system was developed by the Bureau of the Census, U.S. Department of Commerce, in creating a computer file for relating addresses on census questionnaires to census geographic areas for tabulating the 1970 census.

The geographic base file was created by encoding each vertex, intersection or node. The basic assumption was that "...each street, river, railroad track, municipal boundary, or other map feature can be considered as one or more straight line segments. A curved line can be divided into a series of straight line segments." (Census Use Study, Report No. 4, The DIME Geocoding System, p. 5.) A manual digitizing process is used. Since the main function of the ACG/DIME system is to convert standard metropolitan statistical areas' census data into digital form, it does not perform the data manipulation needed in land and resource planning. Actually, "The most significant technical contribution of the DIME geocoding

system is the topological edit." (Census Use Study, p. 25)

7) MAP/MODEL

The MAP/MODEL system was developed by the Bureau of Governmental Research and Service, University of Oregon, Eugene, Oregon. This system is in polygon format and utilizes a manual digitizer as the input device. It is capable of redundant editing, coordinates conversion, dimensioning, alphanumeric retrieval, geographic retrieval (i.e., capable of combining two polygon maps through an overlay technique and updating one map with another), sorting/summarizing and plotting.

8) CGIS

CGIS (Canada Geographic Information System) utilizes an IBM Cartographic Scanner/Plotter which was developed by the Advanced Industry Application group at the IBM SDD Development Laboratory in Kingston, New York. Its data input is by raster scanning. The software system provides computation to convert scanned data into vectorized data which can be plotted out by a linear incremental plotter. The descriptive data (i.e., descriptors) are entered by manual digitization.

9) GELO

The GELO (Geographic Locator) system is converted and modified from the COMLUP (Computer Mapping for Land Use Planning) system which was developed by Region 4, U.S. Forest Service, Ogden, Utah. The system is intended for data storage, retrieval and developing composite maps through a polygon overlay system which utilizes Boolean logic. This system uses a manual digitizer as its input system, and the capability for utilizing the microdensitometer as its input device is now being developed.

2.3. ERGIS and Its Subsystems

An overall review of the ERGIS data bank and the interrelationship among its subsystems is shown in Diagram II on the following page. The major steps include 1) input material analysis, 2) input device

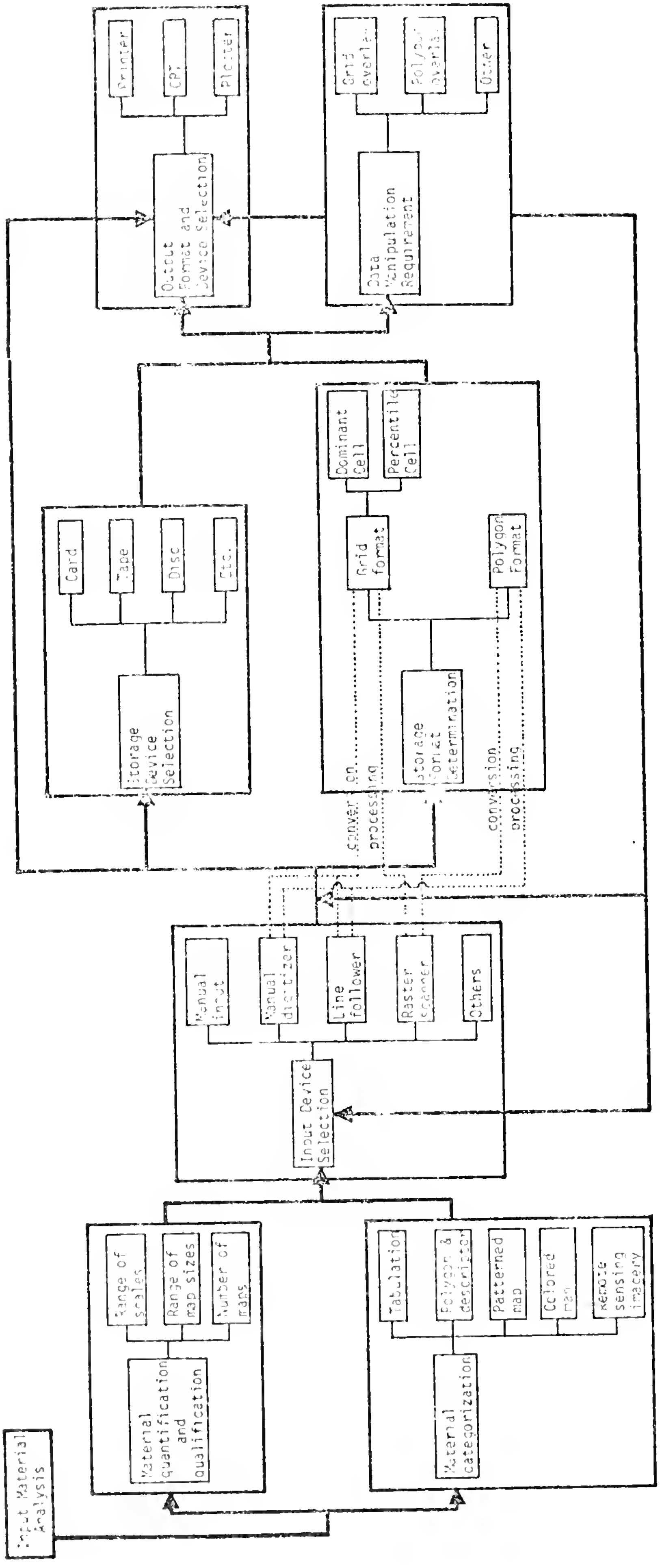

Input Material Analysis
Material quantification and qualification
Range of scales
Range of map sizes
Number of maps
Material categorization
Tabulation
Polygon & descriptor
Patterned map
Colored map
Remote sensing imagery
Input Device Selection
Manual input
Manual digitizer
Line follower
Raster scanner
Others
Storage Device Selection
Card
Tape
Disc
Etc.
Storage Format Determination
Grid format
Dominant Cell
Percentile Cell
Polygon Format
conversion
processing
conversion
processing
Output Format and Device Selection
Printer
CRT
Plotter
Data Manipulation Requirement
Grid overlay
Polygon overlay
Other

DIAGRAM II

selection, 3) storage format determination, 4) storage device selection, 5) output format and device selection, and 6) data manipulation requirements. The following sections provide descriptions of each subsystem.

2.3.1. Data Dissemination, Editing and Update

Before beginning the discussion of the function and specifications of an ERGIS data bank, it is necessary to discuss the characteristics of the four components (or subsystems) of the data bank; it is also necessary to give an explanation of the components that are left out. These components are data dissemination, data editing and data update. Data dissemination relates to the establishment of a communication system. It interconnects the national, state, regional and local/private data banks. It requires not only a hardware and software establishment, but also a standardization that is applicable to all agencies. It is an organizational, system-related effort. No doubt, the federal government should take initiative and responsibility to establish such merit. The component of data editing will be included in the data input and output components. The component of data update can be obtained by combining related parts of data retrieval with related parts of data input.

2.3.2. Data Input Subsystem

Data input relates to the input material analysis and input device determination.

2.3.2.1. Input Material Analysis

Input materials have an adhesive tie with the method of data collection or acquisition.

> The use of remote sensors offers new possibilities for reducing the cost of surveying (data acquisition) for many types of information, for example, land use and traffic flows. However, only a relatively small number of phenomena can be identified from images with

> automatic procedures at present. This causes a most serious restriction on the compilation of extensive data sets from remote sensor imagery. (Saint-Maximum, p. 62)

For the ERGIS data bank, most input materials are in the cartographic map format such as the U.S. Geological Survey (U.S.G.S.) quadrangle maps. The source and format of input materials determine the data input hardware system design as well as software generation. Therefore, categorization of the characteristics of input materials is the first required step prior to getting into the hardware and software system design. Also, quantification and qualification of input materials should be conducted in order to design an efficient system. These characteristics include the range of scales and physical sizes of input maps and the number of maps that need to be digitized. Map scales have a definite effect on output and manipulation accuracy. The design accuracy specification of the input device and the minimum acceptable map scale can be determined only after the required output and manipulation accuracy have been established.

I. Geo-information Characteristics Analysis

As described in the previous section, using overlay techniques to combine geo-information is one of the data manipulation criteria that should be used to design an ERGIS data bank. The first task is, therefore, to analyze the characteristics of the geo-information because these characteristics are the ones with which all hardware and software systems have to deal. All system specifications are to be developed within the constraints of these characteristics.

All geo-information systems can be categorized into three groups: 1) point, 2) line, and 3) polygon. Points represent historical sites, buildings, wells and springs. Lines represent topographic contour lines, highways and streams. Polygons represent soil patterns, woodlots or vegetation patterns, and lakes. Since all geo-information systems are comprised of points, lines and polygons, the functions of data manipulation, input, storage and retrieval must be capable of handling the characteristics of these points, lines and polygons.

The grid system is prevailingly used in computer mapping due to its ready availability. The early grid system was developed under the limitations of the hardware system because most people have easy access to a computer line printer while having very limited access to a manual digitizer and plotter. Converting a geo-information system into a grid system is a modification of study methodology due to the availability of hardware and software systems. This situation has been discussed on page 1 as a risky approach because a grid system is unnatural to the geo-information characteristics. It may also distort the information furnished by geo-information systems to a degree, depending upon the cell size of the grid system when compared with the scale of the geo-information system. But this does not mean we cannot use grid systems. Grid systems have their own advantages, but it is extremely important to conduct a reliability analysis prior to using the system in order to determine the size of the grid cell and to determine whether or not this grid system is compatible with the study intent. The comparison of a grid system with a polygon system will be described in detail in later sections.

II. Input Material Categorization

Input materials can be classified into two major groups. 1) Within this group the characters of data can be divided into two components. One is the delineation of the character by its location which could be a point, a line or a polygon. The other is the descriptor such as the name of a soil type, vegetation community or highway classification. Under this group, four subgroups can be classified:

A) Data in written format such as census tape or tabulation. These data first have to be transferred onto a base map (if any) which has the delineation of all related characters.

B) Descriptor map (see Definitions, Figures 1 and 2). The descriptor could be in either a handwritten or a typewritten form.

C) Delineations of data are shown on the map, but the descriptors are replaced by color patterns such as in Figure 8.

D) Same as C), but the descriptors are replaced by zip-a-tone-like patterns such as in Figure 9.

Figure 8

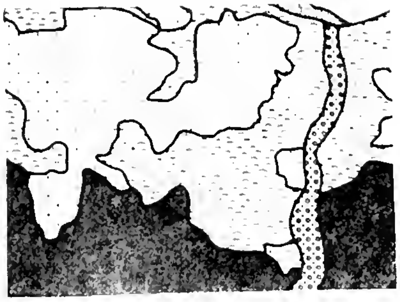


Figure 9

2) Input materials of this group are the remote sensor imagery such as black and white air photos, infrared or multi-band imagery and radar imagery. If these kinds of data input are used, an extra dimension is added to the complexity of the data bank. This includes the interpretation process, either an automated or manual technique, and the process of correcting imagery distortion caused by sensor equipment such as photo lens and the curvature of the earth's surface. Recent research in new equipment, system devices and techniques has accelerated the imagery input method toward full automation.

These two major groups of input materials have their own value. In the foreseeable future, the latter by no means can replace the former. In a developed region or nation, most geo-information materials exist in the former format. In a developing region or country, the geo-information will more likely be collected in the latter format. For the ERGIS data bank, only the former format is considered.

..3.2.2. Input Device Selection

As the format of input material is known, the next step is to design the hardware and software of the input system. Three types of input devices can be grouped:

1) Manual input system, using a manual digitizer to digitize the point, line and polygon. Also, the descriptors are inserted manually.

2) Semi-automated input system, using an automated digitizer and either a raster scanner or a flying spot line follower to digitize the point, line and polygon. If the input material is a colored map, the description can be automatically recorded. If delineation and descriptor of data are both shown on the map, the descriptors must be manually inserted. The functional requirements of this semi-automated input system are as follows:

A) Point/Line - Descriptor Separation

The manual method of line-descriptor separation can be fulfilled either by opaquing the descriptor before scanning the map or by using a magnetic pen to delete the descriptor after the map has been displayed on a CRT. After the removal of the descriptor, the left line image is subjected to scanning. Time may be saved if manual encoding of the descriptor takes place before the descriptors are deleted on a CRT.

B) Point, Line, Polygon Encoding (or Digitizing)

After the removal of the descriptor, the only things that are left on the map are the patterns of data which are presented in a point, line or polygon form. To automatically digitize these figures, a raster scanner or a line follower is needed. A line follower is based on the theory of projecting an intensive light beam or laser beam on the line, thereby dividing the beam into two sections, "a" and "b", as shown in Figure

10. Whenever the measurement of "a" and "b"

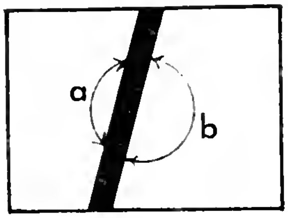


Figure 10

is unequal either by measuring their electric current or by using some other measurable device, the machine will automatically adjust the projection position in order to maintain an equilibrium between "a" and "b". While the beam moves forward, continually readjusting its position, the machine records the position of the beam's coordinates at controlled intervals. If one wants the beam to follow a particular direction after passing an intersection point or moving from an isolated enclosed circle to another, one can use either a manual assistance or software device to consummate the mission. In general, the line follower's traveling speed ranges from a fraction of an inch to several inches per second, depending upon the make of the machine.

The raster scanner uses light beams to travel along a pre-determined path as shown in Figure 11.

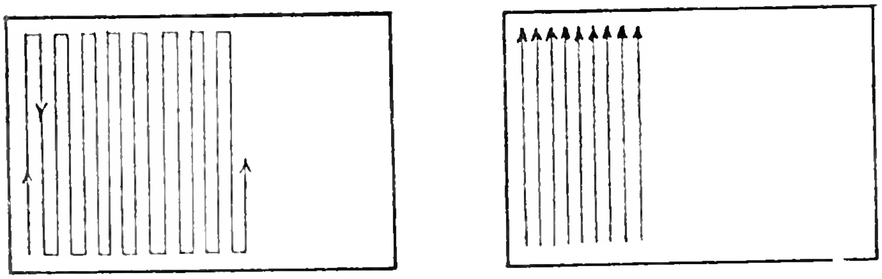


Figure 11

Whenever the beam passes a point or line, due to the change of the quantity measurement, the machine automatically records the coordinates of these changing points. These points represent all black spots (or different grey or color tones) on the map. A scanner map can be displayed on a CRT screen but cannot be directly plotted out through a linear or incremental plotter because the relationship between the points is not indicated (i.e., points are not grouped consecutively to form the line as on the original map). Therefore, regrouping the points or vectorizing the points is essential for plotting purposes, that is, data retrieval. Furthermore, scanned data from a descriptor map without regrouping or vectorization cannot be used for data manipulation - the very purpose of operating an ERGIS data bank. In other words, regrouping or vectorization of scanned data is one of the key factors in constructing an ERGIS data bank.

There are many methods of regrouping/vectorization of digitized data, such as the tracking pattern algorithm and topological skeletonization technique (U.S. Army Engineer Topographic Laboratories & IBM, pp. 7-13). As known, several manufactured systems offer this vectorization capability.

C) Pattern-Descriptor Correlation

As stated previously, if the input material is a colored map, and a raster scanner capable of color separation is used during the scan process, description can be automatically recorded. If a descriptor map is used, there are several methods of correlating the descriptor with the pattern:

Method (A)--It is necessary to associate the descriptor with a point that is located within the area represented by this descriptor as shown in Figure 12. In Figure 12, point "a" or "b" is an arbitrary point within its related polygon. Point "c" or "d"

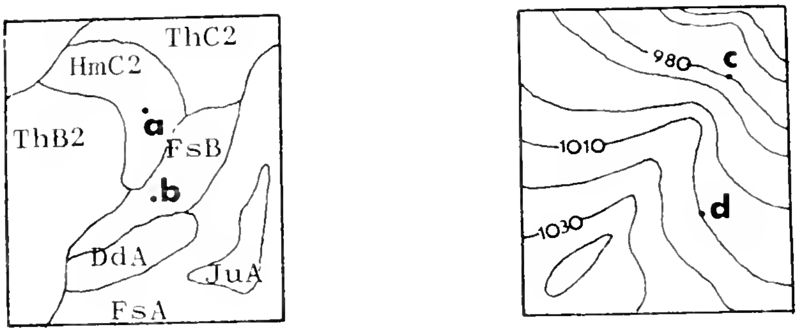


Figure 12

is an arbitrary point located on the line. The coordinates of these points are manually digitized and stored with their related data type's descriptors; as a result of using software subroutine, the lines or polygons can be tied through these points with the information they represent. These points are called "cue points."

Method (B)—The descriptors may be replaced with colored dots. Each color represents a pattern or one type of descriptor, such as a soil or vegetation type. Then the colored dots are scanned and software subroutine used to correlate the color with the pattern.

The degree of automation relates to the character and quantity of input materials. It is a cost-benefit and efficiency related decision. It is absurd to be automatic for the sake of automation only. If the manual approach requires thousands of hours of man power to do the digitizing work, then it is necessary to use the automated approach. Besides, manual digitizing will confront a greater change of human errors and inaccuracy which in the end will require more effort in data correction or editing. But, if the quantity of input materials is small and the descriptors are in a very complicated pattern, then it is better to use a manual

digitizer. In addition, at present, accessibility to a manual digitizer is much greater than to an automatic digitizer.

3) Automated input system, using an automated digitizer and also using a pattern recognition technique to automatically record the descriptors.

If the descriptors that the data bank has to work with are numerous and varied, an extensive software effort or special hardware such as the OCR is required. The variety of descriptors ranges from different typing to off-set styles to handprints. Many commercially manufactured OCR deal with certain commonly used type styles such as the Prestige Elite 72 and the Courier 72 of IBM's Selectric typewriter.

IBM's experimental Scanner/Plotter uses lower harmonic coefficients of the Fourier series for handprint recognition because Fourier transformation is by definition a mathematical series which could easily be implemented by digital techniques on a general purpose computer. Also, it minimizes the symbol irregularities which are consistently present in handprinted texts for the correlation process (P. J. Min, I.B.M., p. 5). If the effort of developing an automated process for descriptor recognition cannot be offset by the time saved from using the manual method in accomplishing the same amount of work, then the manual approach is recommended.

Some manufactured OCR systems are capable of recognizing different styles of descriptors. As the process of character recognition is taking place, certain OCR systems automatically record the X-Y coordinates of descriptors using them as cue points for pattern-descriptor correlating. OCR hardware and software systems have a built-in limit of certain recognizable patterns. All others are considered as non-recognizable patterns (so-called non-recog.) which can be intentionally ignored through

programming. These non-recog patterns include such patterns as points, boundary lines and ink spots resulting from the printing process.

2.3.2.3. Input Subsystem Evaluation

A satisfactory input subsystem for the ERGIS data bank should meet the requirements of efficiency, economy, flexibility, accuracy and reliability. Further discussion of these requirements is as follows:

I. Efficiency and Economy

Since the ERGIS data bank is designed for a state-wide or regional data bank, the amount of input material into the system is enormous, the frequency of use of this subsystem is high, and the time allowed to input all necessary materials is short. Therefore, a manual digitizing process is ruled out. In comparing the present technology of the line follower with that of the raster scanner, the raster scanner has much higher input speed (recorded in run-length coding format), although conversion is necessary if one desires a polygon storage format. Depending on the efficiency of the conversion program, one program may require several times more CPU time than another. Two factors which should be considered in comparing the semiautomated input system with the automated input system are the numerous styles of descriptors and the cost of an automated system, which could be a quarter of a million dollars more. The trade-off, therefore, is worth considering.

II. Flexibility

The more varieties of input materials (as described in the classification of input materials in Section 2.3.2.1.) that can be processed by the system, the higher the flexibility. This flexibility can be achieved either by a manual or an automated digitizer. For an automated digitizer, higher flexibility usually requires a higher level of system sophistication.

III. Accuracy and Reliability

If the input material is a map, then the inherent accuracy of this map is beyond the control of the ERGIS data bank. This inherent accuracy is a factor to be considered due to its influence on the output accuracy. The accuracy of a map can be obtained by comparing the interrelationships between features represented on the map with the actual interrelationships of these features on the earth's surface. The accuracy of a map results from the accuracy of the projection method, the resolution of the hardware that interprets the original material (such as B/W and infrared air photography), the accuracy of map compiling and drafting, either manually or mechanically, and the stability of the medium on which the map is drawn and printed.

National standards for the horizontal and vertical accuracy of topographic maps were adopted in 1941. The standards for horizontal accuracy require that at least 90 per cent of the well-defined map points be plotted accurately within one-fiftieth of an inch on the published map. This tolerance corresponds to 40 feet on the ground for 1:24,000 scale maps and corresponds approximately to 100 feet on the ground for 1:62,500 scale maps. The standards for vertical accuracy require that at least 90 per cent of the elevation interpolated from the contour lines be accurate within one-half the contour interval (U.S.G.S. Topographic Maps, p. 11).

If the input material is from remote sensor imagery, the same factors used for maps have to be considered. But if the input system is directly connected with the remote sensor with an auxiliary system capable of automated data interpretation, then many errors can be eliminated. This is part of automated cartography and orthophotography.

If the input system is using a manual digitizer, possible human error should be considered. Therefore, it is necessary to incorporate an adequate editing process. In order to maintain reasonable accuracy for cartographic standards (about ± 0.004 inch), a cartographic draftsman digitizes lines between 1/30 and 1/10 inch per second, which is a high contrast to the speed (between 4 and 25 inches per second) claimed by the manufacturer (UNESCO/IGU, p. 699). If the error rate of a draftsman is within 2%, it could be

considered a standard performance.

The reliability of input hardware, either a manual or an automatic digitizer, relates to its accuracy (or overall accuracy), resolution, repeatability, linearity, orthogonality, scan curvature and stability. Definitions of these specifications are as follows:

Accuracy is measured by the degree of conformity of a digitizer line to the actual truth. Usually it is measured by the entire digitizer area; this accuracy is called overall accuracy. For example, if an overall accuracy of a digitizer area 42" x 34" is ± 0.003 inches, it means that if a 42" line is digitized it may have a maximum error of ± 0.003 inches; i.e., the digitized result may be either a 41.997" or 42.003" line.

Resolution can be defined as the precision with which a line can be digitized or the minimum separation at which two points can be distinguished by the digitizer. Resolution is usually measured by the number of counts per inch (sample per inch) such as 200 or 500 counts per inch, which is equivalent to 0.005" and 0.002", respectively.

Repeatability is the state of being repeatable at a certain accuracy. It is a measurement of the maximum differences between different results of digitizing the same linear configuration at different times. The measurement unit could be a fraction of an inch such as ± 0.001 inch.

Linearity is related to the scan machine that uses optical elements. Nonlinearity can be obtained by the following formula:[3]

---

[3] From Image Digitizer Model 57 Prelim. Specification Data Sheet I.D.S, Dicomed Corp., Minneapolis, Minn. January 197 .

$$\text{Nonlinearity } (\%) = \frac{(Sa-Sb)}{Sa} \times 100$$

where Sa = linear dimension of object A located at the center of the scan area

Sb = linear dimension of object A located at some arbitrary distance from the center of the scan area

Nonlinearity should be calibrated for the X-axis as well as for the Y-axis.

Orthogonality is a state of being orthogonal between the Y and X scan axes. It is measured by degree or arc. For example, scan axis orthogonality equals ± 0.5 degrees or ± 5 seconds of arc.

Scan curvature is related to the straightness of a traveling path of spots. It can be obtained by the following formula:/3

$$\text{Scan Curvature } (\%) = D/L \times 100$$

where D = maximum deviation from a straight line connecting the scan line end points

L = length of the straight line connecting the scan line end points

Stability can be defined as the quality of enduring, without alteration of its constant course, the encoding function. It relates to the occurrence of mechanical drift or electronic noise. The reasons causing this effect could be numerous; the failure of sending a coding signal and the breakdown of thermal equilibrium are two. To cope with this problem, an adequate editing process is required.

2.3.3. Data Storage Subsystem

Data storage relates to 1) file format determination, 2) coordinates system determination, 3) storage format determination, and 4) storage device selection. Further discussion of these four items is presented in the following sections.

2.3.3.1. File Format Determination

The file format is closely tied to the efficiency of the entire system. It not only saves the data storage space and enhances the random accessibility of data retrieval, it minimizes the CPU time of data manipulation. Random accessibility demands a capability of efficiently retrieving any data type (vegetation community, soil type, traffic flow or population density) by any geo-related sections (township, incorporated village or any arbitrary geo-boundary lines). There are two means of constructing a data file: one is by using one data file per data variable for a unit area with a pre-determined size or the entire data bank region, and the second is by using one data file per unit area for all or multi-variables.

2.3.3.2. Coordinates System Determination

When a data file for the entire study region exceeds a certain size, it is economical to divide the file into small sections or sub-files. This will greatly benefit the data output or retrieval subsystem, because when a small area is to be retrieved from a large file, it is necessary to search through the entire file, thus consuming a great deal of CPU and I/O time. If the entire file is divided into small sections, then only sections that are cut through by the boundary lines of the retrieved area and the sections within the boundary lines are needed for file searching. These sections are represented as the shaded area in Figure 13.

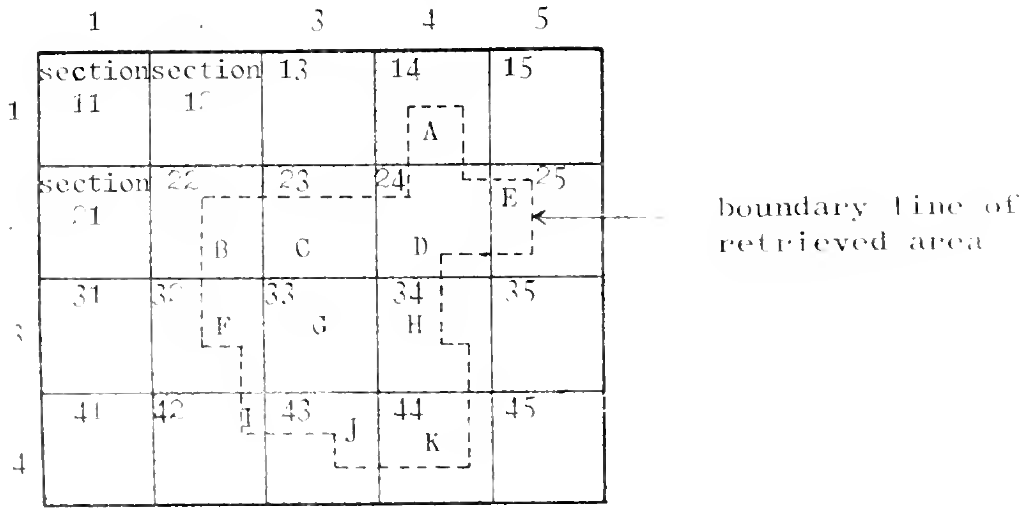


Figure 13

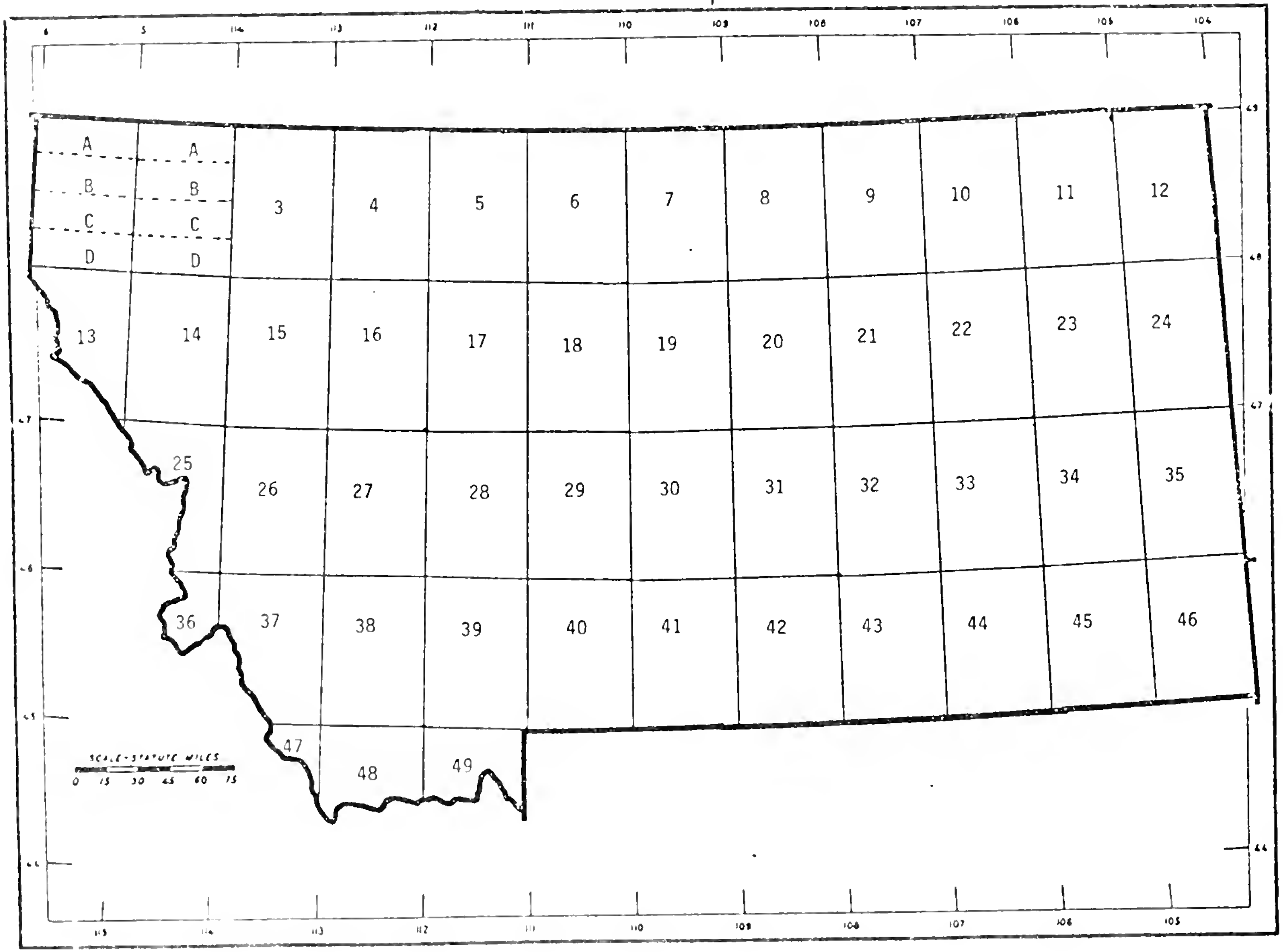
To divide the regional file into small sections, one can use either arbitrary grid systems or geological survey coordinate systems. Examples of these coordinate systems are the UTM grid system, the longitude-latitude system, and the State Plane Coordinates System or political boundaries such as township and county lines. Because of the flexibility of the ERGIS, the selection of the coordinate system or the size of the unit section does not have to meet any external requirements such as compatibility with other regional or state-wide data bank systems. The factors that have to be considered are 1) input device capability, i.e., the size of input material as limited by input device, 2) required input efficiency, 3) randon accessibility of stored data, i.e., the nature of data retrieval in order to achieve efficiency, and 4) data manipulation technique used. As applied to the State of Montana, ERGIS uses the longitude-latitude system. Because of the limitation on the input material size that can be accepted by the scanner, the area bounded by one degree longitude and one degree latitude has been subdivided into four subsections: A, B, C and D. Therefore, the entire state has been subdivided into 49 sections or 196 subsections (see Map I).

2.3.3.3. Storage Format Determination

The data storage format for an input system is rather simple. It takes whatever the input digital format is as its storage format. The retrieval and manipulation systems, however, place many constraints on the format determination.

There are two major groups of storage format: grid format and polygon format. Also, various flagging techniques are used in association with each format to improve the system efficiency. For example, in data manipulation of the polygon system, it is necessary to distinguish or flag the types of polygons formed, regular or center-void. To carry out this task, software programs are required to search and flag center-void polygons. If the number of center-void polygons happens to be very few in the entire data input system, it is reasonable and efficient to use a manual approach to encode their existence.

MONTANA



MAP I

Selection of storage format depends a great deal on the requirements of data manipulation, although input methods used may create an extra burden in reaching the desired storage format. For example, if polygon format is desired, then data input from a raster scanner which is in run-length coding format must be vectorized in order to be stored in the polygon format. On the other hand, if grid format is desired, data input from a manual digitizer or line follower which is in a linear incremental or polygon format must be converted into a grid format before going into the storage device. Conversion of the run-length codes into polygon format or conversion of polygon format into grid format is part of ERGIS capability.

In polygon format, lines are defined by points or vectors; areas are defined by lines. The denser the digitized points or vectors, the closer this line approaches its original configuration. An example is shown in Figures 14, 15 and 16.

Figure 14

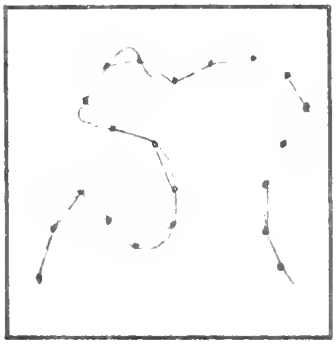


Figure 15

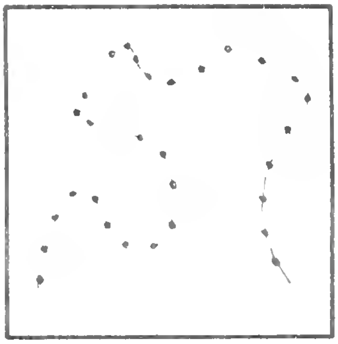


Figure 16

Obviously, the accuracy of the data is building at the expense of the storage space available. For example, if a scanner scans at a resolution of 50 points per inch, a general soil type map at a scale of 4" = 1 mile, for each square mile, will have an average of 5,000 points. For a county with an area of 600 square miles, the scanner will generate nearly three million points. If each point requires a full word, a total of three million words is needed. If

this is stored at a density of 1600 BPI, at least 5,000 feet (space between records is not counted) of magnetic tape is required to accomodate a soil map for one county. Obviously, the reduction of points within the constraints of reliable and accurate data or utilization of another more efficient data storage technique is inevitable.

How to reduce the unused space between data records to a minimum is another efficiency-related issue. Although flagging the data will increase the data storage space, the resultant saving of CPU time for data retrieval and manipulation is definitely worthwhile. This approach of flagging certain data also considers the efficiency of the entire system as a whole and between data bank subsystems.

Comparison of polygon storage format with grid storage format is related to the data retrieval (or output) and manipulation requirements. Further discussion of this comparison follows.

I. Polygon Storage Format vs. Grid Storage Format as Retrieval Criteria Related

Retrieval criteria consist of 1) random accessibility, 2) flexibility, and 3) compatibility, all of which are discussed below.

(1) Random Accessibility

As discussed in Section 2.3.3.2., random accessibility requires data output of any arbitrary geographic boundary area desired (see Figure 13). Assuming data are stored according to each section shown in Figure 13, retrieval of the area bounded by the dashed boundary line makes it necessary to isolate portion "A" from the Section 14 file, portion "B" from the Section [illegible] file, portion "C" from Section 23, portion "D" from Section 24, • • • • • , portion "G" equals Section 33, • • • • • , and portion "K" from Section 44. After isolation or separation of all these portions, it is necessary to merge all the portions through a software effort to form a complete map. Therefore, the following comparison will be based first on the efficiency of file separation, and then on the efficiency of file mergence.

(A) File Separation

In order to separate a geographic area from an existing polygon format data file, the following steps are necessary: (The following discussion is not intended to provide a solution, but merely to reveal the complexity involved in solving this problem.)

1) Read in polygon format data file.

2) Read in the X-Y coordinates of boundary lines forming area "A" which will be separated from original data file read in during step 1).

3) Search out the maximum and minimum X-Y coordinates of each polygon.

4) If the coordinates of polygon I's (I = 1 to n) four corners, X max, Y max; X min, Y max; X max, Y min; and X min, Y min, are outside of area "A," then delete polygon I.

5) If any one (or more) of these four points is located within area "A," check all line segments of this polygon to determine which line segment or portion of a line segment is located within area "A."

6) Reconstruct data file of area "A" according to polygons and their related lines and points.

7) Store, print or plot out new data file.

In order to separate a geographic area from an existing grid format data file, rather simple "do" loops can be used to eliminate all cells outside of boundary lines. Therefore, assuming that the data files have the same complexity and can provide a similar level of accuracy, from the viewpoint of file separation, the grid format will provide higher efficiency than the polygon format.

(B) File Mergence

In order to merge the data file of the polygon format, the following steps are the minimum requirements: (The following discussion is not intended to

provide a solution, but merely to reveal the complexity involved in solving this problem.)

1) Read in data -- for example, data files of area "B" and area "C" that are to be merged.

2) Analyze each data file to determine the polygon type (whether it is a border polygon or a center polygon). A border polygon (shaded polygons of Figure 17) can be defined as any portion (can be a point,

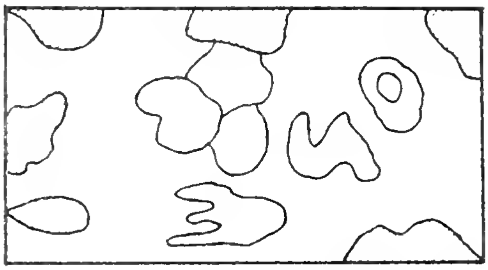


Figure 17

many points, or a portion of a line segment) of a polygon which overlaps with the boundary line(s). Otherwise, it is called a center polygon (non-shaded polygons of Figure 17).

3) Flag all center polygons.

4) Examine all line segments of each border polygon by checking the end points in order to determine whether the line segment is a border line (i.e., line segment which completely coincides with the boundary line, such as line segments (11), (12), (13), (14), (15), (16), (22), (21), (20), (19) and (18) of Figure 18); a border-

center line (i.e., a line segment with one end (or both ends) intersecting the boundary line, such as line segments (1), (3), (6), (8), (9) and (17) of Figure 18); or a center line (i.e., the entire line segment is free of intersection with a boundary line, such as line segments (2), (4), (5), (7) and (10) of Figure 18).

5) Check each border line to determine whether it is a special case A (i.e., border line located on the boundary line that will be merged, see Figure 19).

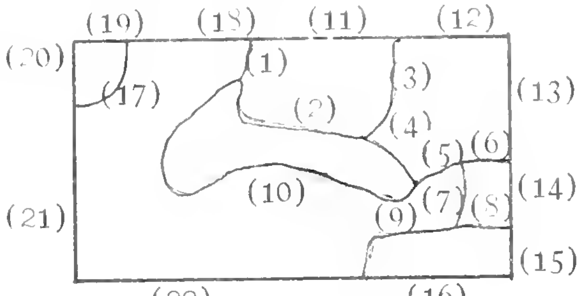


Figure 18

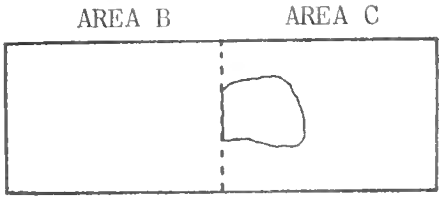


Figure 19

SPECIAL CASE A

If it is not, delete the border line. If it is, flag this line.

6) Match end points of each border-center line of area "B" and "C" to determine whether special case B (see Figure 20), C (see Figure 21) or D (see Figure 22) exists.

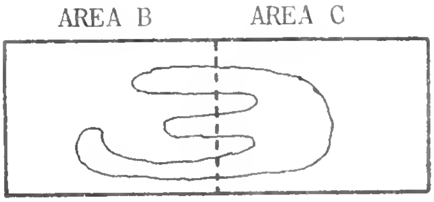


Figure 20

SPECIAL CASE B

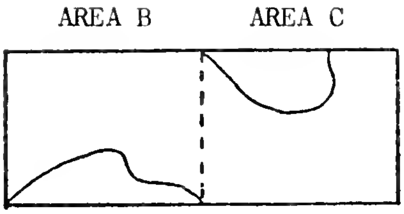


Figure 21

SPECIAL CASE C

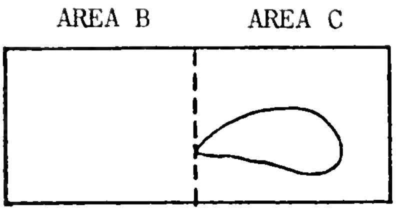


Figure 22

SPECIAL CASE D

7) Solve special case B, C, and D; flag necessary border-center lines and their related polygons. (Note: special cases may not be limited to those described above.)

8) Combine related polygons and lines of area "B" and area "C;" then rearrange the data file.

9) Store, plot or print out new data file of merged areas.

Mergence of the data file of the grid format involves only rearrangement of coordinates of certain cells, a rather simple task of mathematic addition and subtraction. Therefore, from the viewpoint of data file mergence, the grid format is more efficient than the polygon format.

(2) Flexibility

Higher flexibility of data retrieval demands a capability of arbitrary output format. Data stored in a polygon method have the greatest accuracy (i.e., the original inherent accuracy that can be provided by the input device) and the greatest flexibility because these data can be plotted out at any desirable scale. Whether the plot out is an enlargement or reduction in scale, the accuracy of the original data file is preserved (i.e., enlargement will not enhance the accuracy of the original data file). The data can also be converted to the grid system with any reasonable and desirable cell size.

If data were stored in a regular cell size grid system, these data can only be aggregated upward toward a more crude level rather than disaggregated downward toward a finer level. In this grid system, aggregating upward without losing control of reliability can be conducted in only one fashion, that is, using the width or length of the original cell as the interval unit and aggregating in an integral interval as shown in Figure 23. In each cell, whether it is a percentile cell or a dominant cell, the data are not described by location-related coding. Therefore, no method exists that can break the individual cell without losing control of reliability. Aggregating in any fractional or decimal-related interval as shown in Figure 24 is illogical.

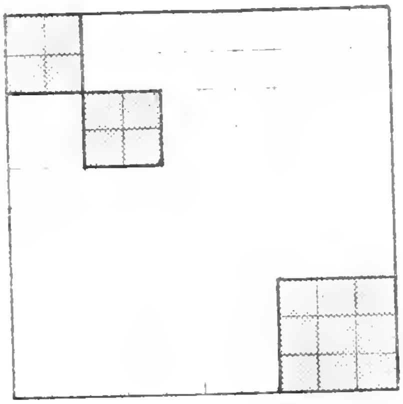


Figure 23

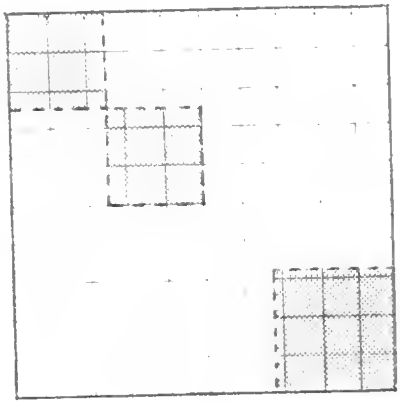


Figure 24

Disaggregated downward, the data will more likely lose their original reliability or accuracy. For example, data type "a" and "b" as shown in Figure 25 are stored in a dominant type, regular size grid system as shown in Figure 26. If it disaggregates

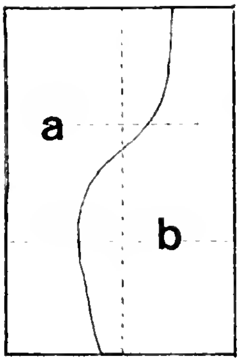
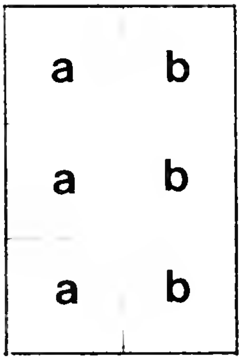


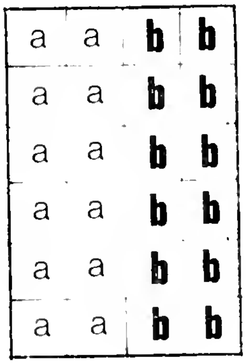
Figure 25



a	b
a	b
a	b

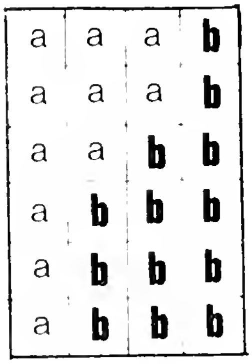
Figure 26

downward, data of Figure 26 will result in a form shown in Figure 27, which is quite different from the data shown in Figure 28 derived from Figure 25



a	a	**b**	**b**
a	a	**b**	**b**
a	a	**b**	**b**
a	a	**b**	**b**
a	a	**b**	**b**
a	a	**b**	**b**

Figure 27



a	a	a	**b**
a	a	a	**b**
a	a	**b**	**b**
a	**b**	**b**	**b**
a	**b**	**b**	**b**
a	**b**	**b**	**b**

Figure 28

directly. The loss of reliability or accuracy could be worse in the percentile grid system. Examples are shown in Figures 29, 30, 31 and 32. Figure 31 is a result of disaggregation from Figure 30, while Figure 32 is a result from Figure 29 directly.

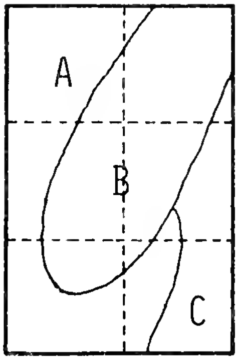
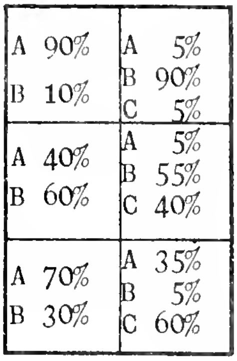
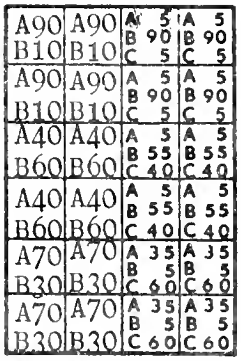


Figure 29



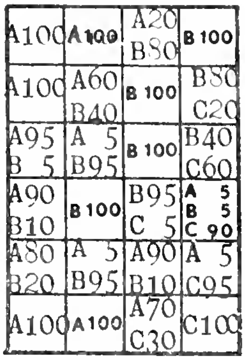
A 90% B 10%	A 5% B 90% C 5%
A 40% B 60%	A 5% B 55% C 40%
A 70% B 30%	A 35% B 5% C 60%

Figure 30



A90 B10	A90 B10	A 5 B 90 C 5	A 5 B 90 C 5
A90 B10	A90 B10	A 5 B 90 C 5	A 5 B 90 C 5
A40 B60	A40 B60	A 5 B 55 C 40	A 5 B 55 C 40
A40 B60	A40 B60	A 5 B 55 C 40	A 5 B 55 C 40
A70 B30	A70 B30	A 35 B 5 C 60	A 35 B 5 C 60
A70 B30	A70 B30	A 35 B 5 C 60	A 35 B 5 C 60

Figure 31



A100	A100	A20 B80	B 100
A100	A60 B40	B 100	B80 C20
A95 B 5	A 5 B95	B 100	B40 C60
A90 B10	B 100	B95 C 5	A 5 B 5 C 90
A80 B20	A 5 B95	A90 B10	A 5 C95
A100	A100	A70 C30	C100

Figure 32

Because the accuracy of the dominant type, micro-cell size grid system is similar to that of the polygon system (i.e., based upon the inherent accuracy of the input material minus the resolution, e.g. 1/100" and 1/400", of an input device such as the raster scanner), this grid system will have flexibility of arbitrary output format similar to the polygon system if the square of the scan resolution is used as the cell size.

The least accurate is the percentile type, regular size grid system because of its relatively large cell size and lack of location specifications within each cell. The ERGIS data bank will provide software to convert the polygon system into a dominant type, micro-cell size grid system, then aggregate it into a percentile grid system if necessary.

(3) Compatibility

Data storage compatibility between two data bank systems or between different data sets within the same data bank depends upon the coordinates system and scale used. For grid systems, it also depends upon the size of the cell. Data compatibility is directly affected by the data input system and data storage format. Different data sets, either from different data banks or the same data bank and with the same coordinates system and scale, are compatible. Through a software effort, one coordinates system or scale can be converted to another.

Data stored in a polygon or micro-cell format have higher compatibility than data stored in a regular cell size grid system because this grid system has constraints due to cell size, as well as due to differences in coordinates system and scale. If data sets use different coordinates systems, even though they have the same cell size, they are incompatible. Examples are shown in Figures 33, 34 and 35. Figures 34 and 35 are derived from Figure 33, but with different coordinates systems. It is obvious that one cannot compare these two sets.

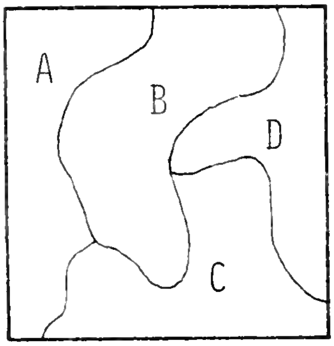
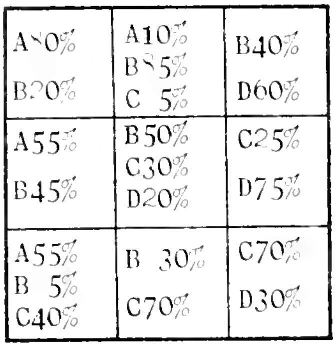
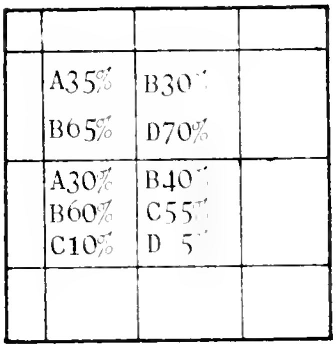


Figure 33



A80% B20%	A10% B85% C 5%	B40% D60%
A55% B45%	B50% C30% D20%	C25% D75%
A55% B 5% C40%	B 30% C70%	C70% D30%

Figure 34



	A35% B65%	B30% D70%	
	A30% B60% C10%	B40% C55% D 5%	

Figure 35

Usually no location specifications are coded within a percentile cell format; one cell systems cannot be converted to other coordinates systems without losing data reliability. The degree of reliability loss depends upon the cell size and the complexity of data. The smaller the cell size and the less complex the data arrangement within each cell, upon conversion into another coordinates system, the less reliability is lost. If the cell is large and the data arrangement is complex, the reliability lost during conversion sometimes can be as high as 100%. If the same coordinates system is used in the grid systems, data stored at a higher or cruder level have a lower level of compatibility.

(4) Conclusion

Based upon the data retrieval criteria discussion presented above, the micro-cell size grid system offers the greatest number of advantages over other systems. It provides the efficiency of random accessibility, greatest flexibility of arbitrary output format, and greatest data compatibility. Although the polygon system provides similar flexibility and compatibility, it has a lower efficiency of random accessibility. The regular cell size grid system is unacceptable to the ERGIS because it is unreliable.

II. Polygon Storage Format vs. Grid Storage Format as Data Manipulation Criteria Related

Based upon the data manipulation criteria of reliability, accuracy and efficiency, the micro-cell grid system offers the greatest advantages. The polygon system offers reliability and accuracy, but is rather inefficient.

2.3.3.4. Storage Device Selection

Many data storage devices such as cards, tapes, drums, and discs are available. For a large bulk of data, cards are not recommended as large quantities are needed, thereby presenting a handling problem. Cards also lack endurance. Tape has the benefit of storing large amounts of data on a relatively small magnetic tape, but it may lack random accessibility. A drum or disc storage device offers long-lasting durability, random accessibility, and relatively - small physical dimensions. Experiments have been conducted in various fields to explore the better storage devices including microfilm or microfiche.

2.3.4. Data Retrieval and Output Subsystem

Because the input and storage systems have already been built into the required output format (either polygon or grid format), the output is only a matter of calling the storage data. The important function of the retrieval system is the establishment of randon accessibility and optional scaling. Random accessibility can be derived by hybridizing the file separation program with the file mergence program. Optional scaling enables the system to plot or print

the output image at the scale desired by the users. Most of the commercially manufactured plotters have a built-in ability of optional scaling.

2.3.4.1. Output Device Selection

There are three major output devices available: 1) line printer, 2) matrix plotter, and 3) linear or incremental plotter, which can be either a drum plotter or a flat-bed plotter. The first two devices are usually used for grid format output. The third device is usually used for polygon format output, but can be used for grid format output if necessary.

The durability of a plotter relates to the sum value of the life length of hardware, the regular maintenance required, and the frequency of repair. The life length of hardware depends upon its mechanism. For example, either a drum or a flatbed plotter uses gears to drive the pen(s). Gears are vulnerable when subjected to continuous friction; therefore, the lifetime of this hardware is approximately five years. But some plotters use the magnetic field to drive the pen(s), not creating any friction. Therefore, the lifetime of such a plotter can be expected to be much longer than that of one using gears. Dr. A. R. Boyle has summarized the costs involved in hardware maintenance and repair in the following passage:

> Regular maintenance is essential in mechanical items such as teleprinters. (Maintenance costs about $25 per month per teleprinter.) Occasional maintenance is required on mechanisms such as plotters. On-call maintenance is preferable for electronic equipment and may be expected to cost $2,000 to $3,000 per annum for a system.
>
> Down-time costs (costs incurred when equipment is unserviceable) depend on whether the machine is in production, and whether operator labor is committed. A reasonable down-time figure in each subsystem might be three months. (UNESCO/IGU, p. 675)

2.3.5. Data Manipulation

Data manipulation, as mentioned before, is determined by the methodology of land and resource utilization. Data manipulation can be divided into two categories: 1) the manipulation of a grid system which includes percentile cell and dominant cell subsystems, and 2) the manipulation of a polygon system. Under each of these two categories are two subcategories. One is to generate a new data set from a known data set that is already stored in the data bank. Examples are generating a slope and aspects analysis map from topographic data, or generating a construction compatibility map from a soils type map. The second is to merge two different data sets. This is known as the overlay technique, and it relates to different mathematical evaluation or combination methods. The following comparison between the polygon overlay system and the grid overlay system is based upon the criteria of reliability, accuracy and efficiency.

2.3.5.1. Reliability and Accuracy

The polygon overlay system, offering an original delineation of data type, has a higher rate of accuracy and reliability than the regular cell size grid system. This is because the data in each cell of the grid system are not location specified. For example, in alignment decision making, as shown in Figure 36, data type "A" represents an incompatible value to alignment selection, while type "B" represents a compatible value.

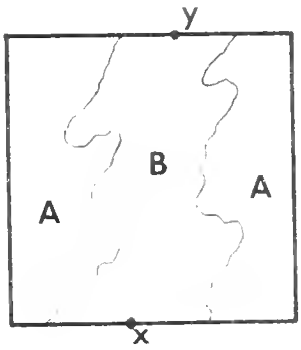


Figure 36

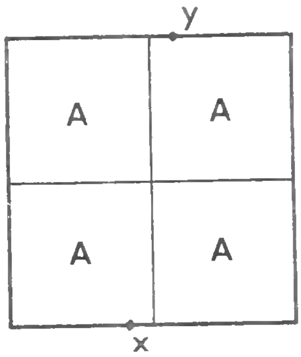


Figure 37

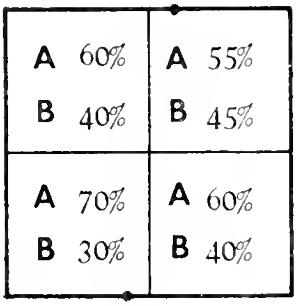


Figure 38

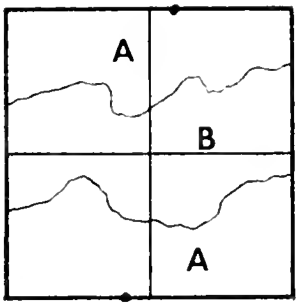


Figure 39

It is obvious that the configuration of data "B" in Figure 36 forms a corridor which is ideal for locating an alignment to connect point X with Y. But if the data are stored in a dominant grid system as shown in Figure 37, they give an illusion of incompatibility in connecting X with Y through these four cells. If a percentile grid system is adopted, as shown in Figure 38, the same set of data could represent a completely different data configuration as shown in Figure 39 (which is incompatible for alignment selection).

The above example demonstrates the unreliability of using the regular cell size grid system. Because the micro-cell size grid system can provide accuracy similar to the polygon system, these two systems have a similar level of reliability.

In a situation where a regular size grid system must be used for the overlay technique, it is necessary to conduct a reliability study to determine the cell size. Cell size determination depends upon 1) the accuracy level of the original data, 2) the configuration complexity of each data set, and 3) the nature of the study. Further discussion of these factors is as follows:

1) The accuracy level of the original data can be obtained from the method described on page 49. If the accuracy of the input map is about ± 500' when compared with the ground truth, it is of no value to use a cell size

smaller than 500' x 500' due to the possibility of the entire cell carrying completely false information.

2) On issues related to the configuration complexity of the data set, it is empirically recommended that no more than three data types should be contained within one cell.

3) The nature of the study (i.e., the study objectives) can be concerned with obtaining either a strategic summary related decision or a detailed field construction work related decision or any decision level in between. A relatively crude cell size is usually favored in a strategic summary study type. But it is suggested that any finer level decision making study should use either a dominant type micro-cell size grid system or a polygon system. The scale selection is also essential.

2.3.5.2. Efficiency

In order to use the overlay technique of superimposing one polygon format map on top of another, the following steps are required. (The following discussion is not intended to provide a solution, but merely to reveal the complexity involved in solving this problem.)

1) Read in data files of areas "A" and "B" which will be overlaid.

2) Search out the maximum and minimum X-Y coordinates of each polygon in these two data files.

3) Flag all center-void polygons.

4) If the area formed by the maximum and minimum X-Y coordinates of polygon i of data file A overlaps with the area formed by the maximum and minimum X-Y coordinates of polygon j of data file B, then it is possible that polygon i will overlap polygon j. Detailed pursuing via the vector-value - method is required.

5) Vector-value method:

Take a point (point ii) from polygon i which has X-Y coordinates located within the proximity of the centroid point's X-Y coordinates of polygon j. Connect point ii with all points (point jj, jj = 1 to n) of polygon j. And obtain the value of vector K (K = 1 to n) which results from measuring the angle formed by line ii-j1 and line ii-j2.

If $\sum_{K=1}^{n}$ vector K = 0^0, point ii is outside of polygon j.

If $\sum_{K=1}^{n}$ vector K = 360^0, point ii is inside of polygon j.

For the special case of a center-void polygon,

If $\sum_{K=1}^{n}$ vector K = 360^0, point ii is inside this center-void polygon. Otherwise it is outside. This includes the case of $1080^0 \geqslant \sum_{K=1}^{n}$ vector K $\geqslant 720^0$ happening when point ii is located within the inner polygon of the center-void polygon.

6) Use the vector-value method to check all points of polygon i in order to determine which points are located inside polygon j and which points are outside.

7) Record the new polygon formed by polygon i's points that are located within polygon j and reconstitute the data of polygons i and j after the area of the new polygon is eliminated.

8) Repeat processes 4 to 7 for all polygons of data files A and B which have the possibility of overlapping each other.

There are several existing polygon overlay programs. One of the pioneer research programs is the MAP/MODEL system; the others include the PIOS (Polygon Information Overlay System) of the Environmental System Research Insititue, Redlands, California, and the program developed by the Calspan Corporation, Buffalo, New York.

The superimposing of two grid format maps is a rather simple mathematic addition as long as the grid systems of two maps are compatible with each other.

It is obvious that the consequences of using the polygon overlay system are great: this system requires an enormous storage space and a great amount of CPU time. It appears that the micro-cell size grid system is more efficient to use for the overlay technique of data manipulation because of the accuracy level provided if a run-length coding format (or any other similar coding format) is used.

2.3.6. Conclusion

ERGIS is established for use in land and resources management which is data manipulation related. The most commonly used type of data manipulation, the overlay technique, can be performed most efficiently through use of the dominant type micro-cell size grid system. Therefore, for purposes of data manipulation, the data should be stored in this type of system.

For a regional or state-wide land and resources management data bank with a large amount of data that needs to be digitized, constantly maintained and updated with a minimum of error, an automatic digitizer is essential.

As indicated in Diagram II, input device - selection is influenced by input material analysis and data manipulation requirements. As examined previously, the input device for ERGIS should, no doubt, be a raster scanner. To ensure that the raster

scanner and related input system will meet the necessary requirements, the following subsection - (2.3.7.) presents a discussion of The minimum required specifications.

In order to simplify the input material categorization, the input material of ERGIS should be limited to descriptor maps with different colored dots representing different descriptors and colored maps.

ERGIS should provide the following capabilities: 1) file separation and file mergence in order to achieve random output ability, 2) vectorization of scanner data which can then be plotted out through a linear plotter for display purposes, and 3) conversion of a polygon system into a micro-cell grid system.

2.3.7. Specification Requirements of the ERGIS Input System

1) Capable of handling input material sizes up to 24" x 30".

2) Capable of scanning at a resolution of 50, 100, 200 and 400 samples per inch or higher for both X and Y axes.

3) Capable of separating black from white and also capable of distinguishing sixteen different grey levels with gradually increased intensity from white to black.

4) Capable of digitizing color by separating and dividing the entire visible color spectrum evenly into at least 250 segments.

5) If input material is a color map or color photo, after scanning this input material, the device shall be capable of a matrix output with each cell color coded. For example, if a 3" x 3" colored map is scanned at a resolution of 100 samples per inch, the result should be a 300 cell x 300 cell matrix with each cell color coded as one of 250 segments.

6) Output color matrix shall be stored in run-length coding format with either vertical or horizontal or both directions compressed.

7) Capable of scanning the same map at different times and at different positions in the drum with the scan result always the same.

8) Drum should be registered with vertical lines which parellel the scan paths and horizontal lines. Each registered line - should be calibrated. Therefore, the scanner can be instructed to scan only the desired rectangle size located on any portion of the drum.

9) Capable of removing the data from any designated area after the scan result is displayed on a CRT or any other display device. Also capable of inserting desired data - type(s) to any location(s) of the scanned data file.

10) CRT Terminal should be parallel interfaced to a mini computer and capable of simultaneously displaying the scanning activity with capability of enlarging and reducing the actual scan image by any reasonable factor.

11) Capable of displaying the scan result - through a matrix plotter at the same scan resolution and also capable of enlarging and reducing the actual scan image by any reasonable factor.

12) Should be in full operational condition for 95% of its running time within five years after installation providing that the operational agency follows all maintenance requirements.

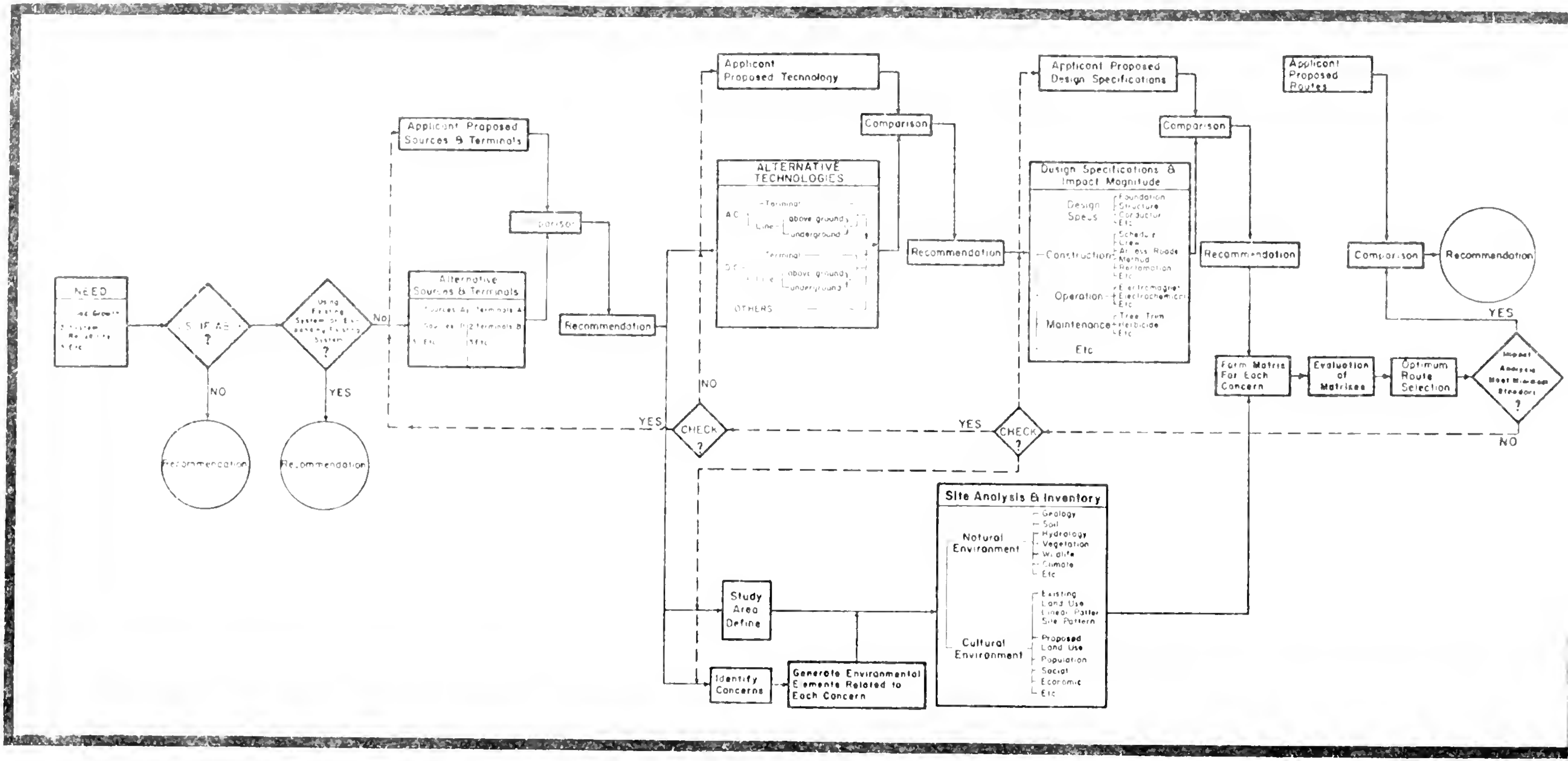
For a partial list of digitizer manufactures, see Appendix I .

3.1. Introduction

In this case study, a joint application filed with the Montana Department of Natural Resources and Conservation by Montana Power Company, Puget Sound Power and Light Company, Portland General Electric Company, Washington Water Power Company and Pacific Power and Light Company for a certificate to construct two 500 KV transmission lines from Colstrip to Hot Springs, Montana, will be utilized. The proposed facilities consist of two single-circuit 500 KV lines in a 300-foot right-of-way. Because an existing double-circuit 230 KV transmission line from Colstrip to Broadview, Montana, could be converted to a single-circuit 500 KV line, only one additional 500 KV line is needed for that section. Therefore, for this case study, the 330-mile Broadview to Hot Springs section of the route will be utilized.

3.2. Methodology

The method of transmission corridor study utilized in this project employs a systematic planning process to meet the decision-making requirement. The accompanying diagram (Diagram III), entitled "Transmission Corridor Study Methodology," offers an overview of the approach. Six processes are used, as shown in the diagram. These are 1) justification of the need, 2) utilization or expansion of existing systems to accommodate the need, 3) determination of electricity sources and terminals (i.e., system alternatives), 4) transmission technology selection, 5) transmission corridor selection, and 6) impact evaluation. This methodology provides a measure of organizing and simultaneously directing and executing a complex series of separate, but interrelated, social, economic, environmental and engineering studies. Due to the dynamic nature of the methodology, some processes are conducted in hierarchial order while others are carried out concurrently in order to improve efficiency. Certain processes are conducted in hierarchial order because the results of prior processes will dominate the research direction of following processes. The initiation and study of a given process without the required previous step may result in wasted work or erroneous findings. For



TRANSMISSION CORRIDOR STUDY METHODOLOGY

DIAGRAM III

example, if the inventory of environmental elements is initiated before the need for the proposed facility can be established, the inventory may later be proven unnecessary (if the need is found unjustifiable). However, in certain cases, special measures can be used to avoid the above described situation. These special measures have to be generated on a case-by-case basis.

Because all the above mentioned methodology processes except the transmission corridor selection are less related to this study, and also have been analyzed in detail and published in the Montana Department of Natural Resources and Conservation's report entitled Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 & 4, 500 - Kilovolt Transmission Lines and Associated Facilities, Volume Four Transmission Lines, further discussion of these processes will be descriptive in nature. The assumed results of the first four processes will also be included. The transmission corridor selection process will utilize portions of the ERGIS data bank to demonstrate the system's applicability and potential.

Further explanation of each process is as follows:

3.3. Justification of the Need

3.3.1. General Discussion

In general, the need for a transmission line arises if one or both of the following situations exist:

1) Supply the load growth requirement

Due to the electricity consumption - growth of an area, a transmission line(s) is required to transmit electricity from a source, which can be either a generation plant or a substation, to the load center or the existing transmission system(s) through a substation. In this case, the study of the area load growth becomes a prerequisite. The conventional method of studying load growth is based on the historical growth rate of an area with an adjustment made to incorporate the special, known facts that likely will

affect future growth. In recent years, for a large complex region, an economic simulation model based on selected parameters has been used. Although this simulation model may give accurate predictions, the worthiness of trading-off years of model development, monitoring and periodic updating still remain to be proven.

2) Increase reliability

In order to insure a constant supply of electricity to a load center, a transmission system should be capable of absorbing certain degrees of line outage or voltage drop. If this requirement cannot be met by an existing system, an extra transmission - line(s) may be needed.

3.3.2. Assumed Result

Assume the load growth of the Pacific Northwest over the next decade warrants an additional 1400 megawatts (MW), and assume Colstrip generating Units 3 and 4 are the best alternative to obtain this 1400 MW. (In fact, both these assumptions are contradictory to the Montana Department of Natural Resources and Conservation's findings.) The need for an electric transmission system is therefore established.

3.4. Utilization or Expansion of Existing Systems to Accommodate the Need

3.4.1. General Discussion

If the need is established, the next step is to decide upon measures to serve the need. Prior to constructing a new transmission line, the existing system is examined in order to conclude whether or not it can be expanded to accommodate the need. Examples of ways to expand the existing system include replacing conductors and replacing both tower or pole structures and conductors. The latter, in some cases, might require widening of the right-of-way. In general, expansion of the existing system

results in less environmental impacts, but not necessarily in less cost.

3.4.2. Assumed Result

No existing line (or lines) has the potential to be expanded to accommodate the amount of power (1480 MW, including power generated from Colstrip Units 1 and 2) that needs to be delivered to the Bonneville Power Administration's transmission grid. Therefore, new transmission lines are inevitable.

3.5. Determination of Electricity Sources and Terminals (i.e., System Alternatives)

3.5.1. General Discussion

If expansion of the existing system is not feasible, construction of a new transmission line is necessary. Therefore, alternative electricity - sources, terminals and intermediate terminals (if any) must be established and a comparison made based on installation cost, engineering and environmental impacts (including natural, land use, social and economic elements) in order to select an optimum source and terminals.

Intermediate terminals, in general, are used to 1) supply more remote (distant) further land growth of an intermediate-terminal-related area as compared to the need for the proposed, or 2) increase the reliability of the intermediate-terminal-located cost due to the detour caused by connection of the source point with the intermediate point.

Without determining the optimum source and terminal, the next process of defining the study area and conducting the environmental inventory may later be void. This and all successive steps of the methodology can be grouped into two major categories: engineering design related and environment related. All engineering steps are intimately related and affected by each other. Any change made within a step may trigger a change of design for all the other steps. For example, a change of electricity source

may result in using D.C. transmission rather than A.C., which in return demands different design specifications. Also, close interrelationships exist between engineering and environmental steps. For example, in order to minimize the impacts on the environment to meet certain required standards, certain engineering design features may have to be changed. On the other hand, a change in engineering design specifications may involve different impacts on the environment. As a result of these inter-and intra-relationships, checkback loops are employed in the methodology to ensure that all the relationships are considered. Only the most important loops are indicated on the diagram.

3.5.2. Assumed Result

Because of the potential environmental impact on the Magruder Corridor and surrounding wilderness areas, the possibility of selecting a terminal in northeast Oregon is ruled out. Hot Springs is selected as the western terminal of the two 500 KV lines because of the total distance involved and the facilities already existing there.

Because of the stability and reliability requirement, an intermediate switchyard is needed to tie the two 500 KV lines together. This switchyard can feasibly be located anywhere between Great Falls and Butte.

3.6. Transmission Technology Selection

3.6.1. General Discussion

After the electricity source and terminals have been determined, two series of steps, one engineering related and the other environment related, can be conducted concurrently.

Various transmission technologies include various voltages of A.C. and D.C. and above ground and underground transmission. Conventionally, the selection of technology has been based solely on the installation cost. D.C. lines are used for long distance, direct transmission of large amounts of

power without any intermediate terminals. Underground transmission is only applied to lower voltage lines. Comparisons are made based on factors of installation cost, engineering and impacts on the environment in order to select an optimum technology.

3.6.2. Assumed Result

Because of the need to deliver power at intermediate points, the lesser reliability of single D.C. lines and the cost involved, two 500 KV, A.C. transmission lines are chosen as the proposed transmission system.

3.7. Transmission Corridor Selection

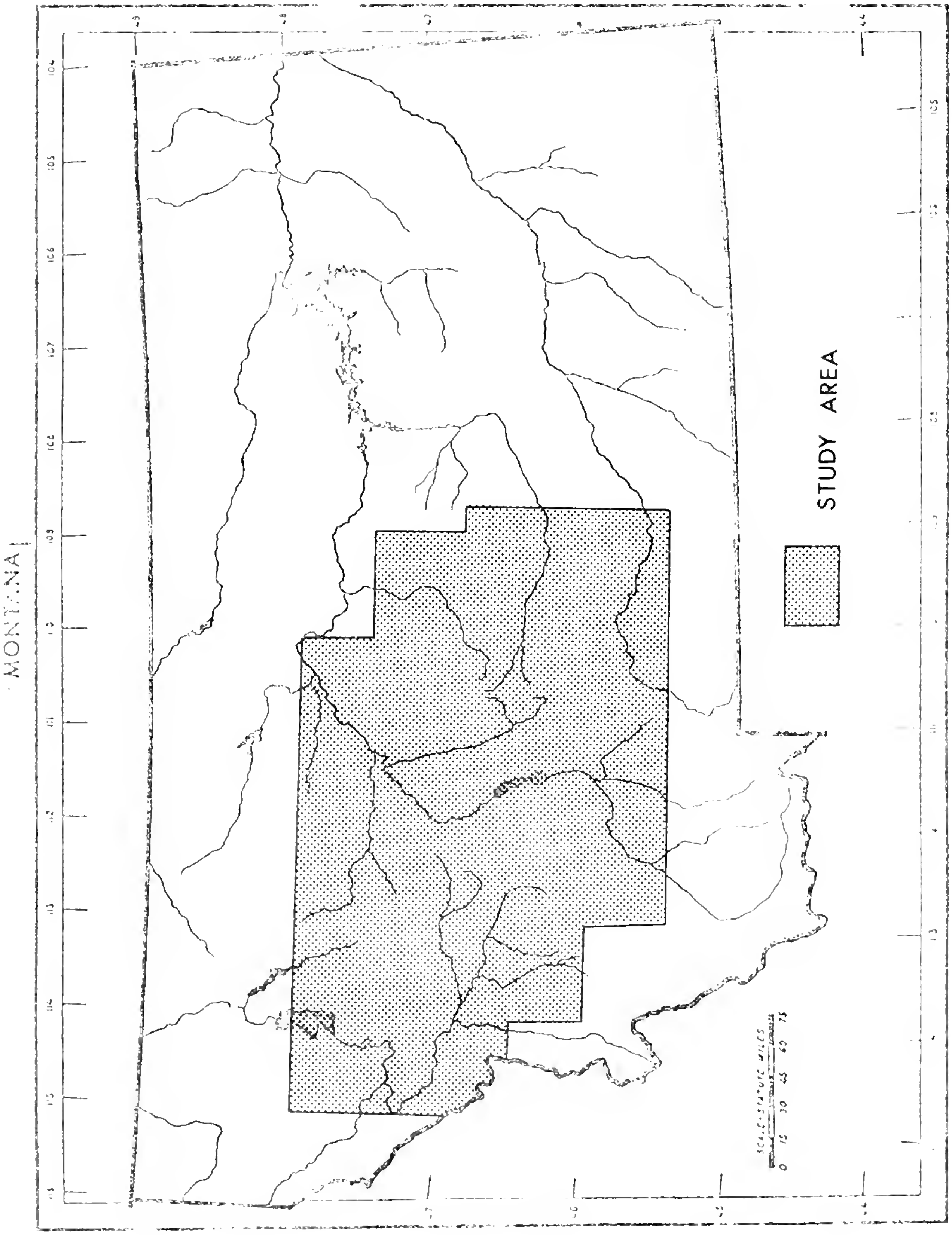
In order to select the transmission corridor, subprocesses are developed as follows:

3.7.1. Definition of the Study Area

A geographic area large enough to include all reasonable routes for the proposed lines between Broadview and Hot Springs is chosen for the study area. This area, 42,000 square miles in total and covering approximately two-sevenths of Montana, is shown on the locater map on the next page. The area includes all or parts of Yellowstone, Musselshell, Carbon, Stillwater, Fergus, Golden Valley, Sweet Grass, Wheatland, Judith Basin, Park, Gallatin, Meagher, Cascade, Choteau, Teton, Pondera, Broadwater, Madison, Jefferson, Silver Bow, Deer Lodge, Powell, Granite, Ravalli, Missoula, Lewis and Clark, Flathead, Lake, Sanders and Mineral counties.

3.7.2. Determination and Analysis of Engineering Design Criteria/Specifications and Impact Magnitude

Transmission line characteristics that are considered for corridor selection are as follows:


MONTANA
STUDY AREA
SCALE-STATUTE MILES
0 15 30 45 60 75
104
105
106
107
108
109
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111
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113
114
115
116
49
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45
44

1) Various construction methods and related impact magnitudes of the following items:

   A) Right-of-way clearance

   B) Temporary and permanent access roads

   C) Staging sites

   D) Foundation digging

   E) Tower erection

   F) Conductor stringing

   G) Construction crew

   H) Construction camp site (if any)

2) Physical presence of the lines

   A) Right-of-way

   B) Self-supporting towers

   C) Guyed wire towers

3) Operational characteristics and impact magnitude of the following items:

   A) Electrostatic effects

   B) Electrochemical reactions

   C) Electromagnetic effects

      i) Radio interference

      ii) TV interference

      iii) Other communication related interference

   D) Audible noise

   E) Heat

4) Maintenance

  A) Regular maintenance

  B) Emergency maintenance

Various construction methods and design characteristics have different impacts on the environment. On the other hand, various mitigative measures can be used to limit construction impacts or to specify the design in order to minimize impact. Therefore, the construction methods and design of the transmission lines shall continuously interact with the corridor selection process and its related impacts until a final corridor is delineated.

3.7.3. Identification of Concerns

Criteria used for corridor selection vary from region to region depending upon the characteristics of the natural and cultural environment of the area studies. A set of criteria has been generated for the study of these 500 KV lines as follows. A selected transmission corridor shall have:

1) Least impact on natural ecological systems, including least impact on vegetation, wildlife, hydrology and soil.

2) Least impact on existing human settlement, which includes least physical intrusion on dwelling areas, least TV and radio interference, etc.

3) Least installation and maintenance cost, including least cost of land acquisition, least material and construction costs and least maintenance cost.

4) Least impact on agricultural production, including least impact on dry crop farming, irrigated land and ranching operations.

5) Least impact on forestry production

6) Least impact on recreation activity

7) Least visual impact

8) Least impact on future land use

9) Greatest line reliability

10) Maximum utilization of existing right-of-way

During the process of identifying concerns, it is essential to make sure that the magnitude of each concern stays at relatively the same scale, i.e., scale homogeneity exists between concerns. Possible overlap between the content of each concern should be avoided.

An optimum corridor usually can be generated to fulfill each concern. However, due to the conflicting nature of some concerns, an optimum corridor for one concern may be unacceptable for another. "Trade-offs" between concerns will be discussed later.

3.7.4. Identification of Environmental Elements That Shall Be Used For Optimum Corridor Selection For Each Concern

A set of environmental elements is needed in order to select a corridor that will fulfill the requirement of each concern. For example, to define a corridor with least impact on the wildlife system, determination of wildlife habitat by species and key areas, including wintering ground, migration routes, etc., should be made. This is a lengthy and continuous process. Prudence and patience must be exercised to carry out the process correctly.

It is self-evident that for each concern various individuals of different disciplinary expertise are needed in order to identify the list of environmental elements.

Environmental elements related to each concern described in Section 3.7.3. are listed in the matrices labelled Figures 40 through 44 in Section 3.7.6.

3.7.5. Site Analysis, Inventory and Computer Mapping

Typical methods of inventorying environmental elements include searching for existing available data, remote sensing interpretation and field surveys.

Environmental elements identified in Section 3.7.4. are inventoried and published in the Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 & 4, 500 Kilovolt Transmission - Lines & Associated facilities. The inventory maps - which will be used in this case study include the Physiography Map, Sediment Risk Map, Existing Vegetation Types Map, Tree Size Map, Forest Stocking Map, Specially Managed Areas Map, Existing Land Use-Site Patterns Map, Range Vegetation Types Map, Range Condition Map, Existing Land Use-Linear Patterns Map, and Potential Land Use Map.

After data inventory, it is necessary to store the data in digital format for efficient data retrieval and manipulation. Because an overlay technique is used for data manipulation in this case study, it is more efficient to use a micro-cell grid system than a polygon system. A range of from 5 to 10 times the CPU time can be saved in this way. Since printed color maps and the negatives that were used in the printing process are available, they will be used as input material.

The scale of the input maps is approximately 1" =14.0 miles. The size is 11.5" x 10.5". If scans at a resolution of 100 samples per inch are utilized, the cell size will be 770' x 770'. The study area consists of two million cells. According to the rules under the Montana Major Facility Siting Act, the first proximation of transmission corridor selection requires delineation of a two-mile-wide corridor. Therefore, a 770' x 770' cell will provide the accuracy required. The inherent accuracy of the inventory map should also be considered. This accuracy depends on the accuracy of the base map, the method and number of times the information has been transferred from one map to another, etc.

The printing of two million cells for each map requires 170 pages of standard computer print-out pages and will be approximately 11' x 17' in size. To

avoid the bulkiness of these print-outs, and also for display purposes, an aggregated form of grid system is used. Every 6 cells x 10 cells are grouped into a cell represented by the dominant environmental element within those 6 x 10 cells. The print-outs of each inventory map(Sediment Risk Map, Existing Vegetation Types Map, Tree Size Map, Forest Stocking Map, Specially Managed Areas Map, Existing Land Use-Site Patterns Map, Range Vegetation Types Map, Range Condition Map, Land Use-Linear Patterns/Transportation—Highway Map (portion)) follow.

3.7.6. Matrix Formation, Rating and Optimum Corridor Selection for Each Concern

For each concern listed in Section 3.7.3. above, a matrix can be formed with all transmission line characteristics described in Section 3.7.2. listed on the Y-axis (vertical) and related environmental elements listed on the X-axis (horizontal). To select an optimum corridor for each concern, related environmental elements are compared to each other on the basis of suitability for corridor location. Then a rating system is used to define the various categories of comparative suitability. An example of a rating system is as follows:

Very unsuitable	represented by -3
Unsuitable	represented by -2
Moderately unsuitable	represented by -1
Moderately suitable	represented by 1
Suitable	represented by 2
Very suitable	represented by 3
No relation (Suitability unknown)	represented by 0

Rated matrices for five concerns are used as examples. These are Figure 40, "Matrix for Alignment of Least Damage to Natural Ecological System;" Figure 41, "Matrix for Alignment of Least Construction Cost;" Figure 42, "Matrix for Alignment of Least Disruption to Existing Forestry Production;" Figure 43, "Matrix for Alignment of Least Disruption to Existing Agricultural Production;" and Figure 44, "Matrix for Alignment of Maximum Utilization of

Existing Right-of-Way." According to the instruction of the rated matrix, a suitability map can be obtained by converting each environmental element (such as Mountain -1 and Alluvial -2) of that inventory map according to its assigned suitability value. Then, a composite suitability map can be produced from which an optimum corridor can be delineated.

A composite suitability map is produced by using an overlay technique to combine related inventory maps or suitability maps. For example, consider the alignment of least damage to the natural ecological system (Figure 40). Six inventory maps will be superimposed on top of each other and combined (see schematic diagram shown in Figure 45). The method of combination depends on the relative importance value or ratio assigned to each inventory map or suitability map. For this example, the importance ratio among these maps is: Physiography: Hydrology: Sediment Risk: Vegetation Types: Tree Size: Forest Stocking = 5:10:10:20:10:10, or 1:2:2:4:2:2:. Using the importance ratio to multiply the suitability value assigned to each cell of that map, add all the maps together. A composite suitability map is thus produced (Figure 45). Composite suitability maps for the five concerns are as follows: "Composite Suitability Map for Alignment of Least Damage to Natural Ecological System," "Composite Suitability Map for Alignment of Least Construction Cost," "Composite Suitability Map for Alignment of Least Disruption to Existing Forestry Production," "Composite Suitability Map for Alignment of Maximum Utilization of Existing Right-of-way." Using each composite suitability map, an optimum transmission corridor can be selected according to the line that links two terminals (i.e., Broadview and Hot Springs) with the highest sum of suitable values.

3.7.7. Final Corridor Selection

Final corridor selection results from comparisons made between concerns. These comparisons involve different issues. Certain concerns contain dollar values only, while some imply quantifiable values, and others relate to abstract values. In general, no single corridor can fulfill all concerns, but the possibility of finding one should not be ruled out. Therefore, in the first comparison all unsuitable values of all concerns should be combined, and a

Existing Right-of-Way." According to the instruction of the rated matrix, a suitability map can be obtained by converting each environmental element (such as Mountain -1 and Alluvial -2) of that inventory map according to its assigned suitability value. Then, a composite suitability map can be produced from which an optimum corridor can be delineated.

A composite suitability map is produced by using an overlay technique to combine related inventory maps or suitability maps. For example, consider the alignment of least damage to the natural ecological system (Figure 40). Six inventory maps will be superimposed on top of each other and combined (see schematic diagram shown in Figure 45). The method of combination depends on the relative importance value or ratio assigned to each inventory map or suitability map. For this example, the importance ratio among these maps is: Physiography: Hydrology: Sediment Risk: Vegetation Types: Tree Size: Forest Stocking = 5:10:10:20:10:10, or 1:2:2:4:2:2:. Using the importance ratio to multiply the suitability value assigned to each cell of that map, add all the maps together. A composite suitability map is thus produced (Figure 45). Composite suitability maps for the five concerns are as follows: "Composite Suitability Map for Alignment of Least Damage to Natural Ecological System," "Composite Suitability Map for Alignment of Least Construction Cost," "Composite Suitability Map for Alignment of Least Disruption to Existing Forestry Production," "Composite Suitability Map for Alignment of Maximum Utilization of Existing Right-of-way." Using each composite suitability map, an optimum transmission corridor can be selected according to the line that links two terminals (i.e., Broadview and Hot Springs) with the highest sum of suitable values.

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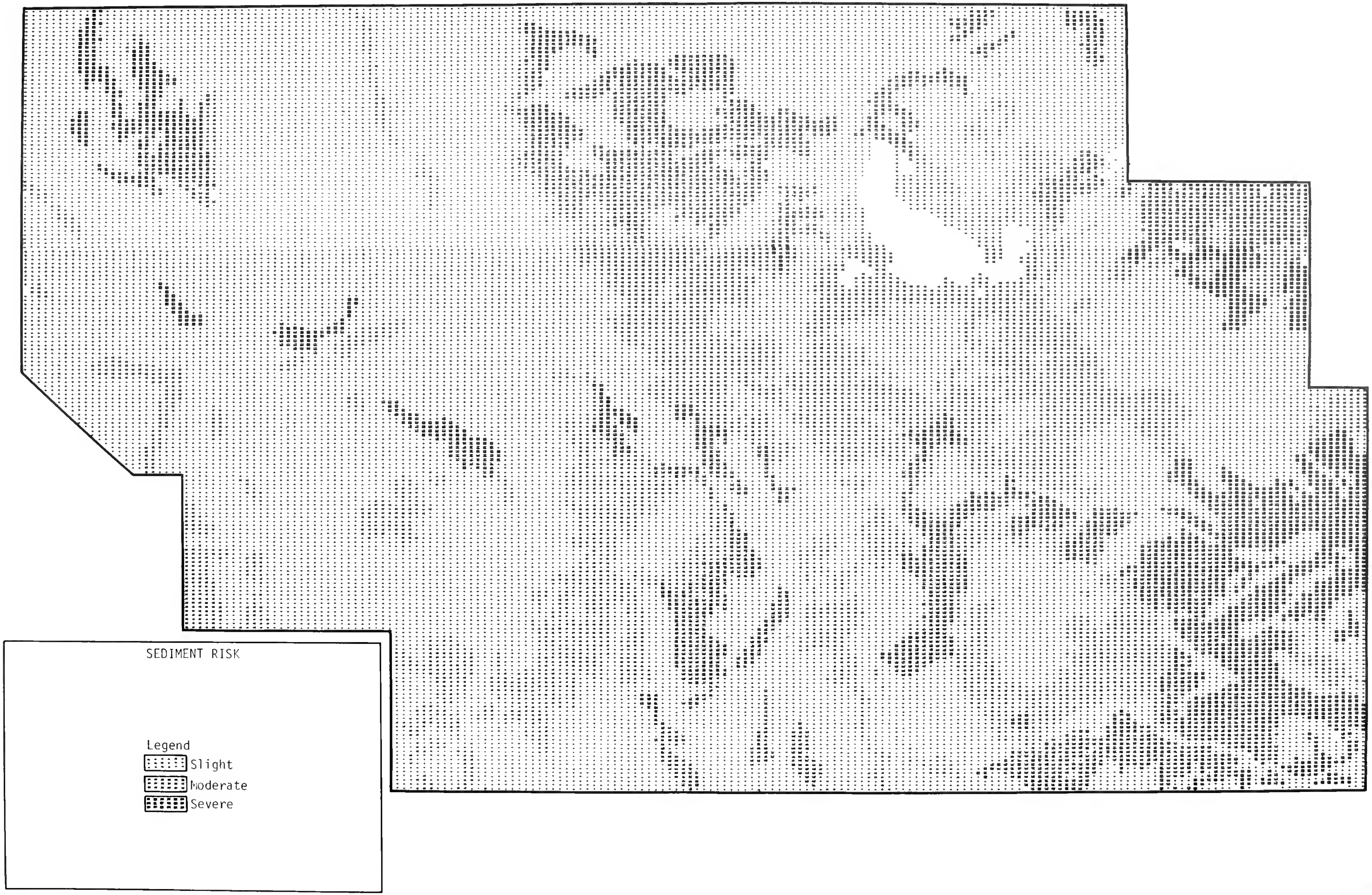
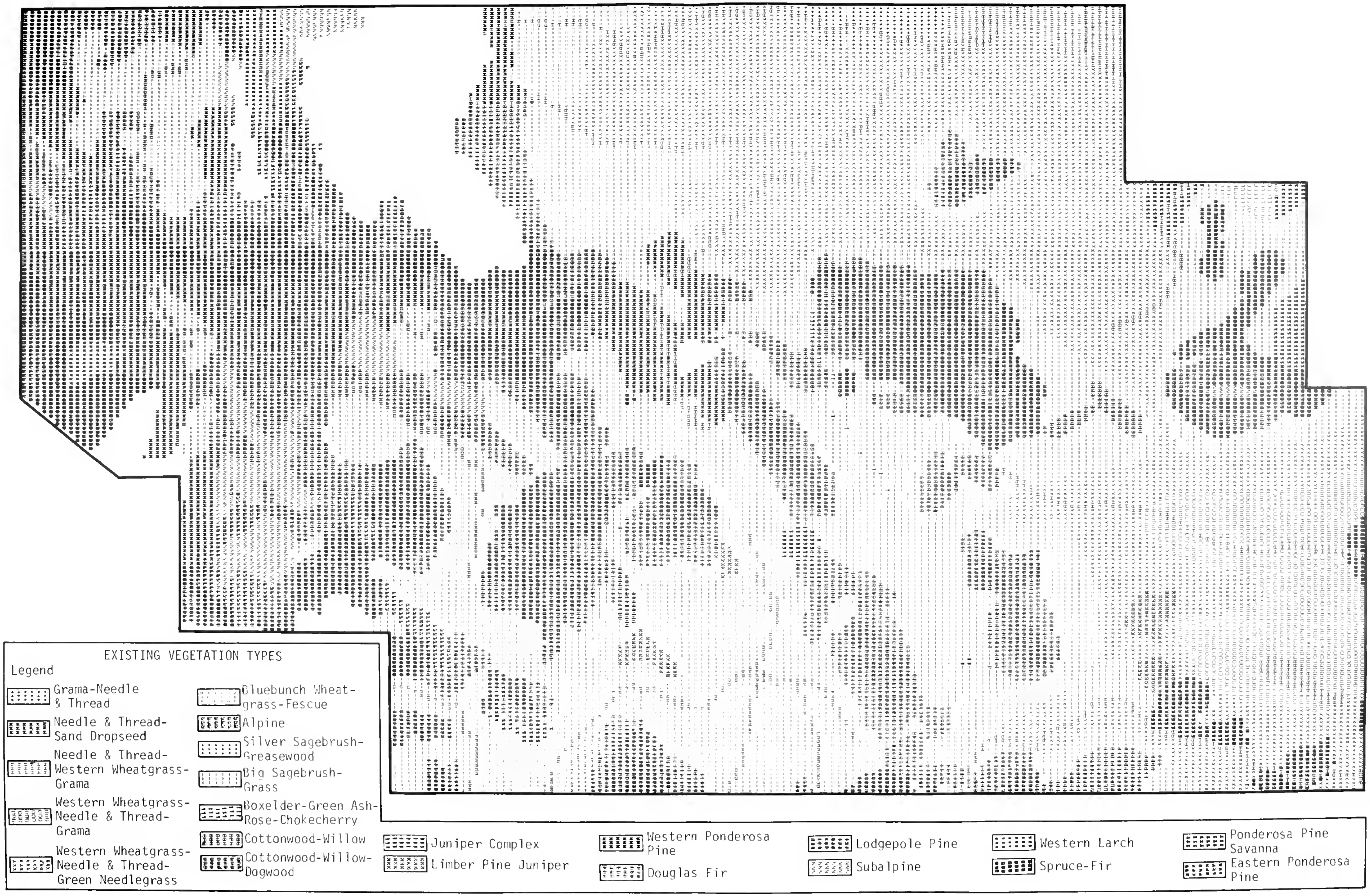
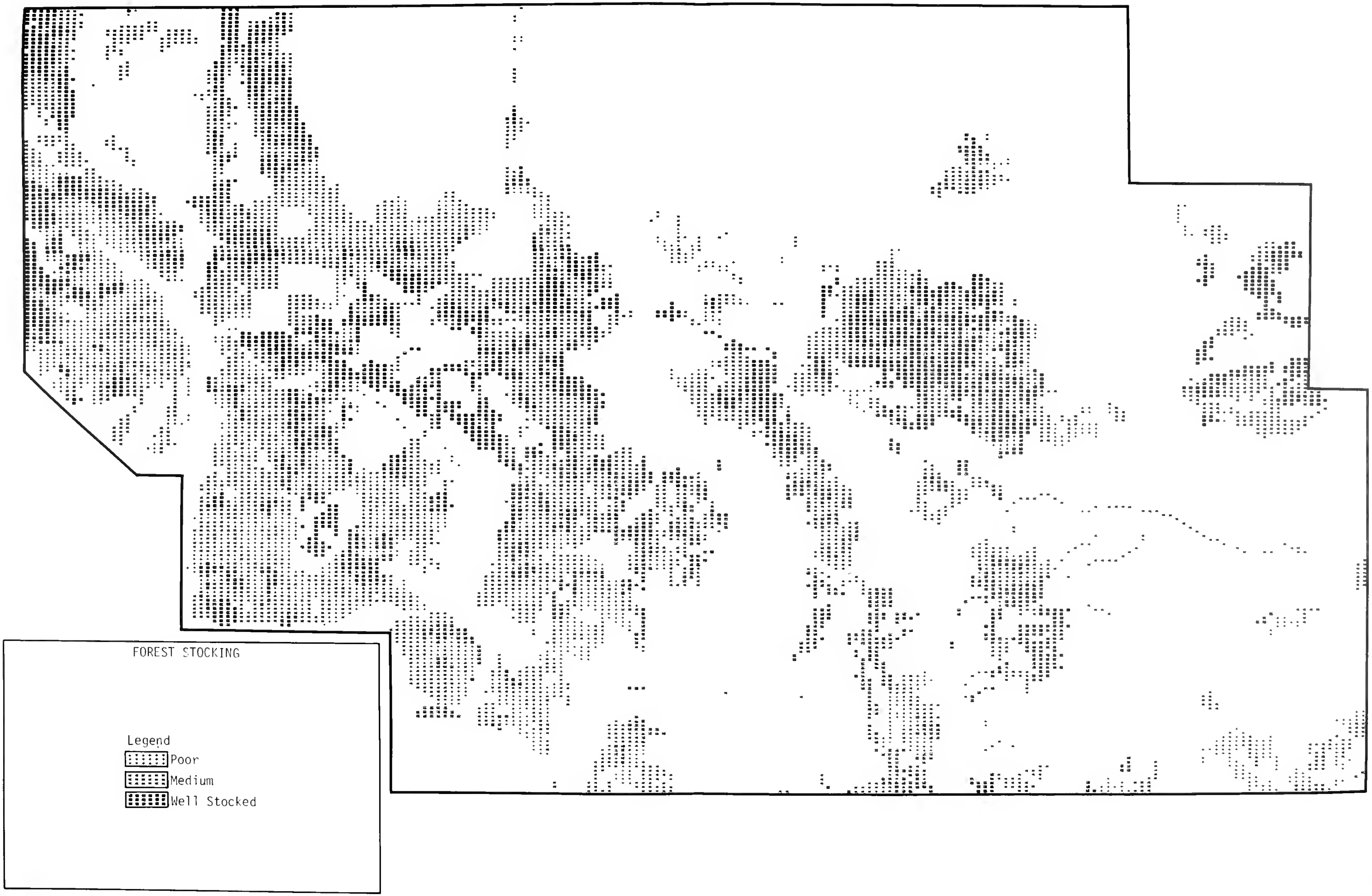
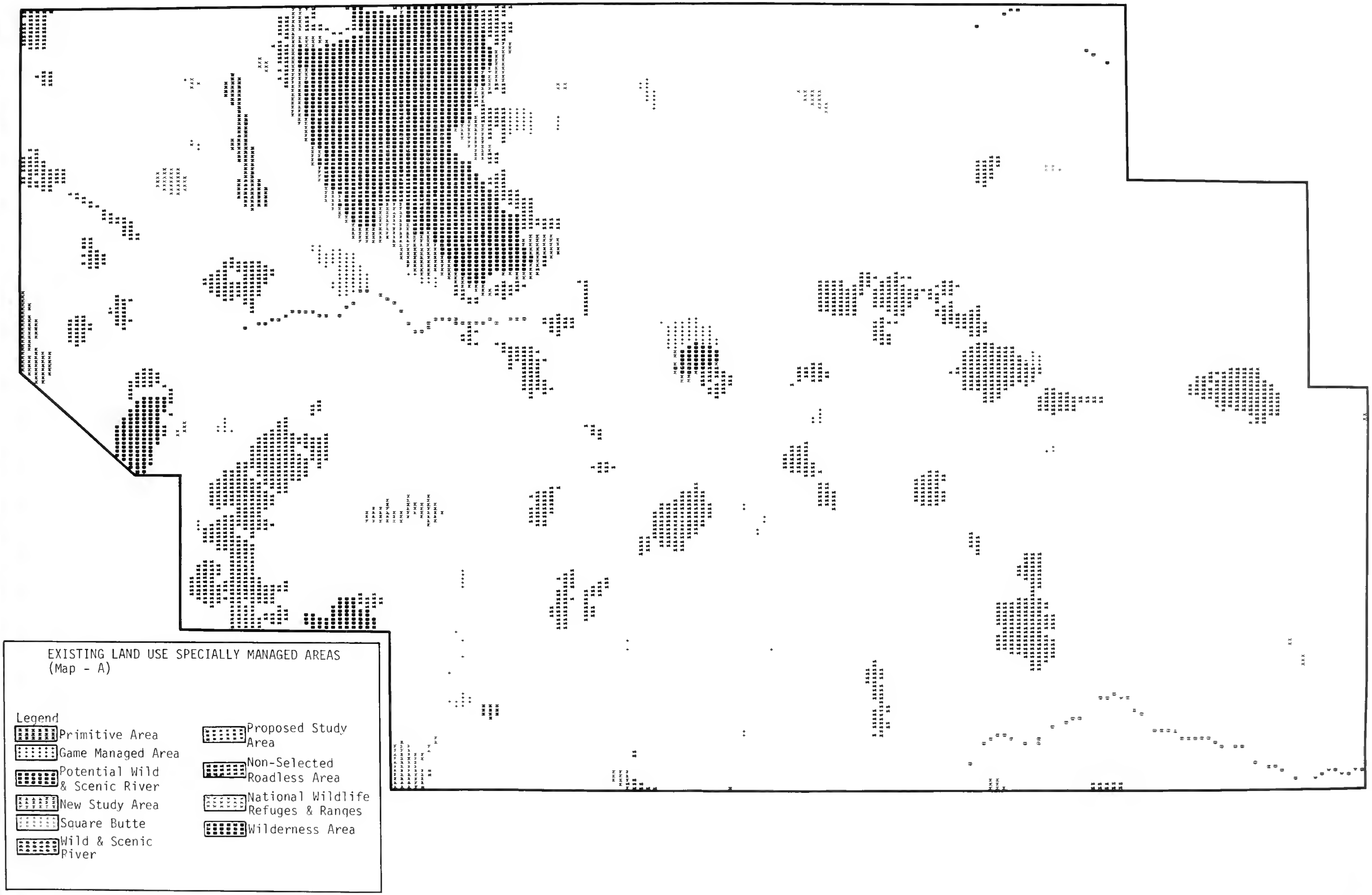

SEDIMENT RISK


EXISTING VEGETATION TYPES
Legend
Grama-Needle & Thread
Needle & Thread-Sand Dropseed
Needle & Thread-Western Wheatgrass-Grama
Western Wheatgrass-Needle & Thread-Grama
Western Wheatgrass-Needle & Thread-Green Needlegrass
Bluebunch Wheatgrass-Fescue
Alpine
Silver Sagebrush-Greasewood
Big Sagebrush-Grass
Boxelder-Green Ash-Rose-Chokecherry
Cottonwood-Willow
Cottonwood-Willow-Dogwood
Juniper Complex
Limber Pine Juniper
Western Ponderosa Pine
Douglas Fir
Lodgepole Pine
Subalpine
Western Larch
Spruce-Fir
Ponderosa Pine Savanna
Eastern Ponderosa Pine

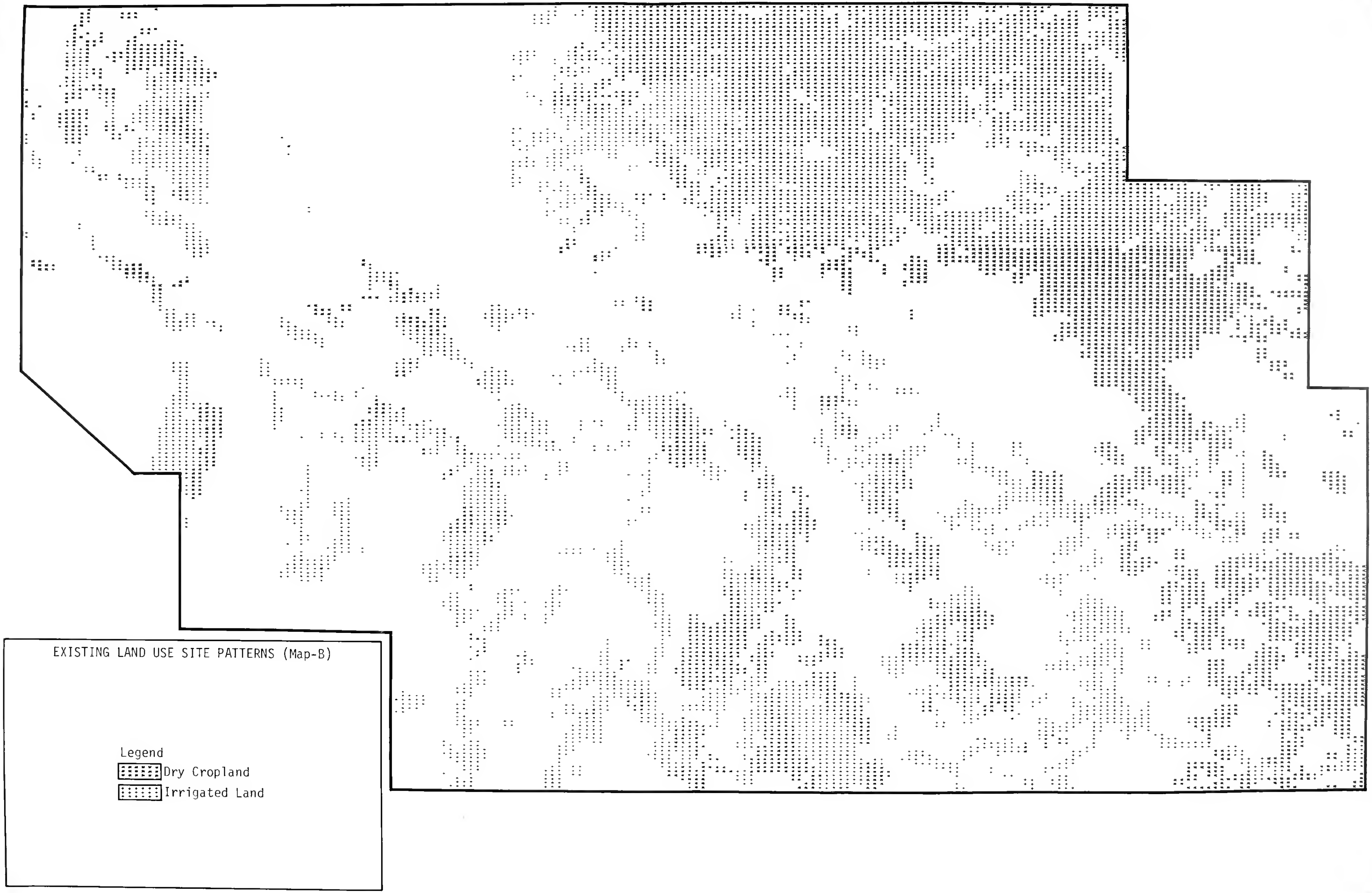

TREE SIZE
Legend
Deforested
Less than 5" DBH
9" - 5" DBH
Greater than 9" DBH



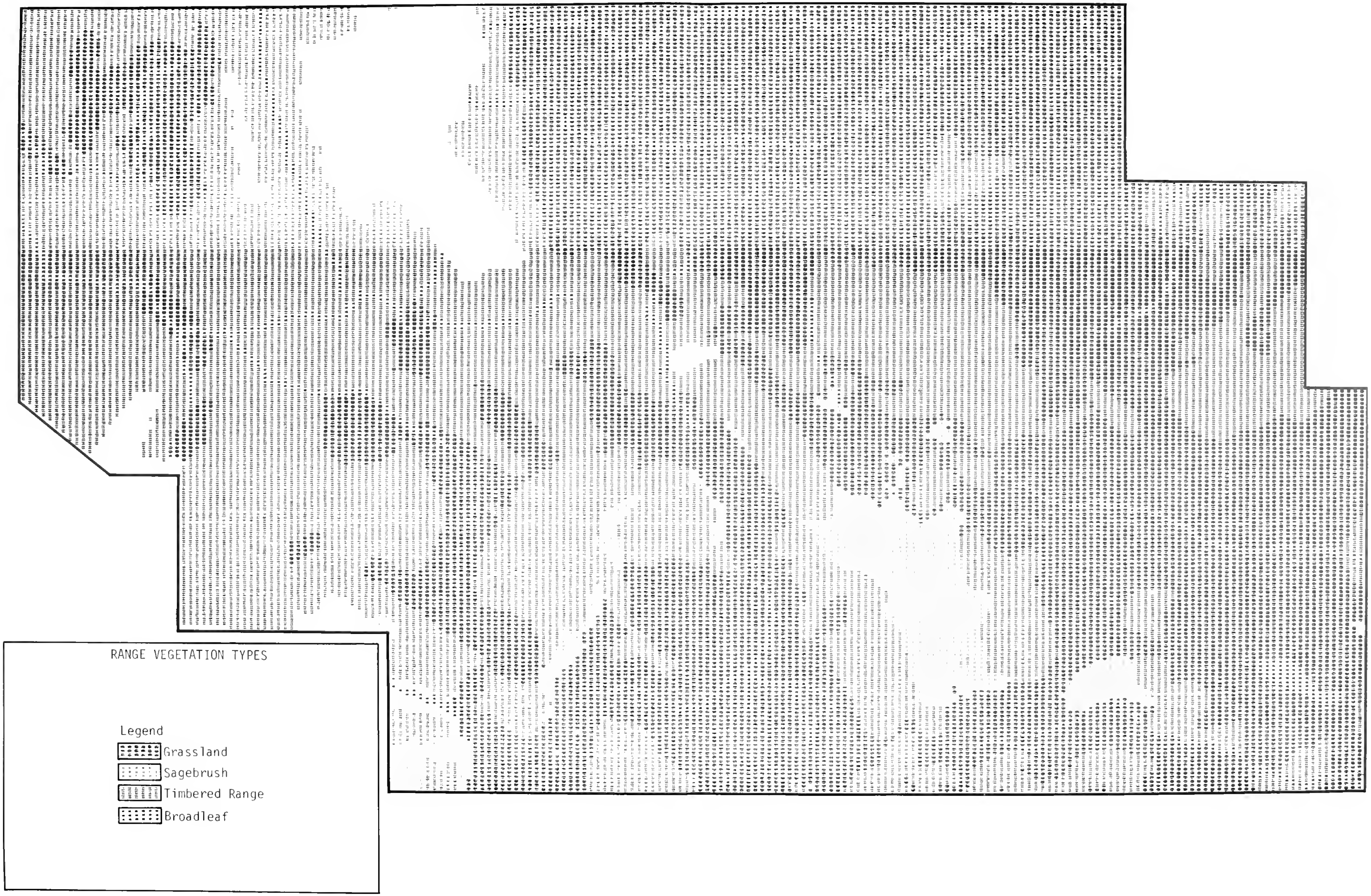
FOREST STOCKING



EXISTING LAND USE SPECIALLY MANAGED AREAS
(Map - A)



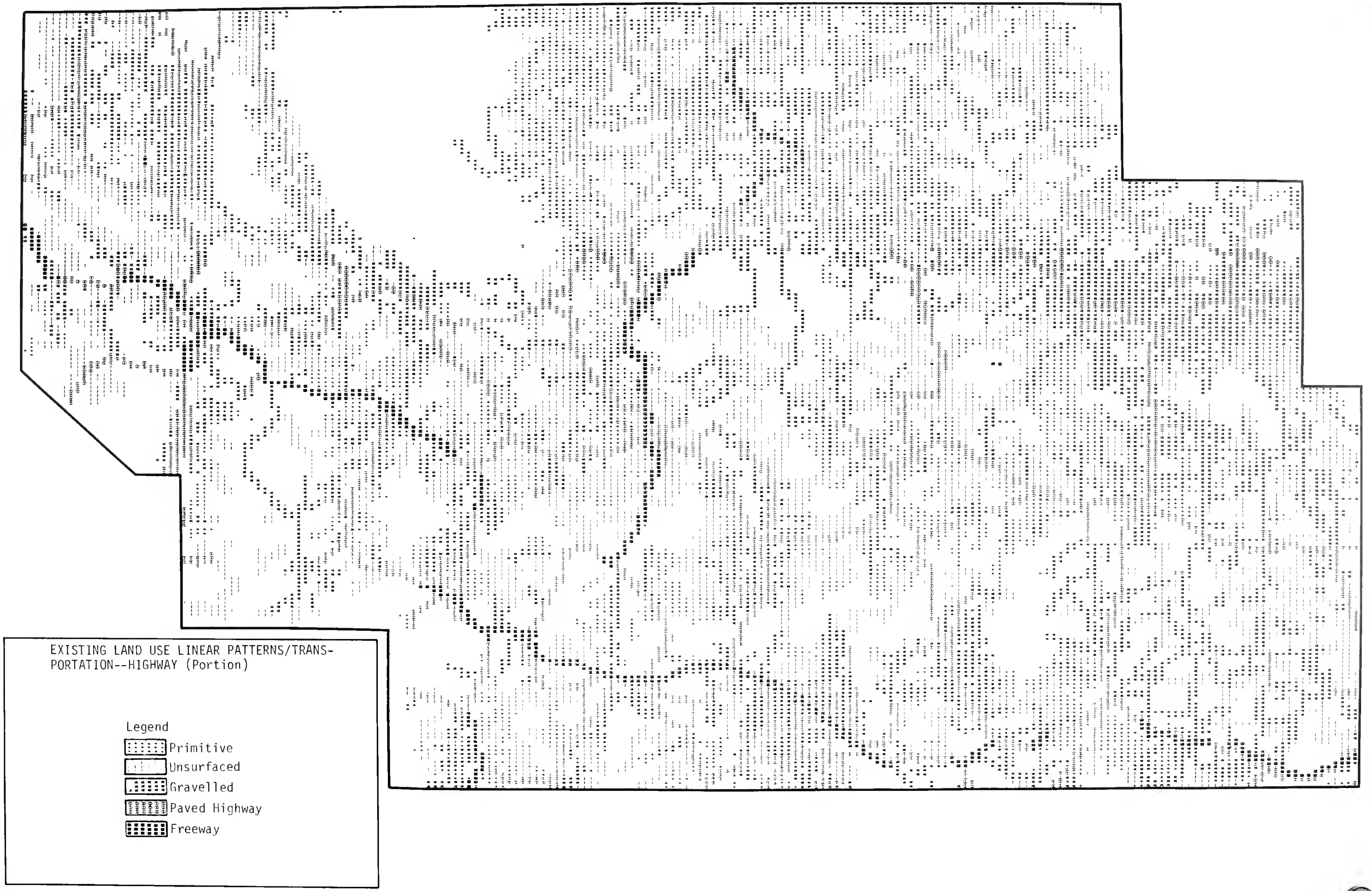
EXISTING LAND USE SITE PATTERNS (Map-B)


RANGE VEGETATION TYPES
Legend
Grassland
Sagebrush
Timbered Range
Broadleaf

RANGE CONDITION

Legend

- ▨ Very Poor
- ▨ Poor
- ▨ Fair
- ▨ Good
- ▨ Excellent



EXISTING LAND USE LINEAR PATTERNS/TRANSPORTATION--HIGHWAY (Portion)

TRANSMISSION CORRIDOR STUDY MATRIX

Model Type: **Least Damage to Natural Systems**

Rating Categories:
X = Unknown
6 = Very Compatible
5 = Compatible
4 = Moderate Compatible
3 = Moderate Incompatible
2 = Incompatible
1 = Very Incompatible
0 = No Relation

			Natural Elements												
				Seismic Risk			5% Physiography								
		Environmental Elements	Geologic Hazard Areas	Zone 1 - Slight Risk	Zone 2 - Mod. Risk	Zone 3 - Major Risk	Mountain - 1	Mountain - 2	Mountain - 3	Mountain - 4	Mountain - 5	Foothill - 1	Foothill - 2	Foothill - 3	Foothill - 4
		Transmission Line Characteristics													
		Transmission Line as a Whole Function (Rating row)													
Construction		R.O.W. Clearance													
		Access Roads - Temporary or Permanent													
		Staging Site													
		Construction Camp Site (if any)													
		Foundation Digging													
		Tower Erection													
		Conductor Stringing													
		(Rating row)	1	0	0	0	1	2	1	1	1	2	3	1	2
		Construction Crew (Rating row)	3	0	0	0	0	0	0	0	0	0	0	0	0
Operation	Physical	Right-of-Way													
		Tower Form I - Self Support													
		Tower Form II - Guyed Wire													
		Conductor													
		(Rating row)	1	0	0	0	0	0	0	0	0	0	0	0	0
	Electrical	Electrostatic													
		Electrochemical													
		Electromagnetic													
		Radio Interference													
		TV Interference													
		Other Communication Related Interference													
		Audible Noise													
		Heat													
		(Rating row)	0	0	0	0	0	0	0	0	0	0	0	0	0
Maintenance		Regular													
		Emergence													
		(Rating row)	1	0	0	0	2	3	2	2	2	3	3	2	3
		Final rating	1	0	0	0	1	2	1	1	1	2	3	1	2

			Natural Elements																
			5% Physiography										10% Hydrology				10% Sediment Risk		
														Stream					
		Environmental Elements	Basins - 1	Basins - 2	Plains - 1	Plains - 2	Plains - 3	Plains - 4	Plains - 5	Plains - 6	Alluvial - 1	Alluvial - 2	Lakes & Reservoirs	Major	Minor	Intermittent	Severe	Moderate	Slight
		Transmission Line Characteristics																	
		Transmission Line as a Whole Function (Rating row)																	
Construction		R.O.W. Clearance																	
		Access Roads - Temporary or Permanent																	
		Staging Site																	
		Construction Camp Site (if any)																	
		Foundation Digging																	
		Tower Erection																	
		Conductor Stringing																	
		(Rating row)	3	3	3	3	1	3	2	3	2	1	1	1	1	1	1	2	3
		Construction Crew (Rating row)	0	0	0	0	0	0	0	0	0	0	3	3	3	3	3	0	0
Operation	Physical	Right-of-Way																	
		Tower Form I - Self Support																	
		Tower Form II - Guyed Wire																	
		Conductor																	
		(Rating row)	0	0	0	0	0	0	0	0	0	0	3	3	3	3	2	3	0
	Electrical	Electrostatic																	
		Electrochemical																	
		Electromagnetic																	
		Radio Interference																	
		TV Interference																	
		Other Communication Related Interference																	
		Audible Noise																	
		Heat																	
		(Rating row)	0	0	0	0	0	0	0	0	0	0	X	X	X	X	0	0	0
Maintenance		Regular																	
		Emergence																	
		(Rating row)	3	3	3	3	2	3	3	3	3	2	2	2	2	1	2	3	3
		Final rating	3	3	3	3	1	3	2	3	2	1	1	1	1	1	1	2	3

			Natural Elements														
			35% Vegetation														
			Vegetation Types 15%														
		Environmental Elements	Subalpine	Lodgepole Pine	Spruce - Fir	Western Larch	Douglas fir	Western Ponderosa Pine	Eastern Ponderosa Pine	Ponderosa Pine Savannah	Limber Pine - Juniper	Juniper Complex	Cottonwood-Willow-Dogwood	Cottonwood-Willow	Boxelder-Green Ash-Rose-Chokecherry	Big Sagebrush-Bluebunch Wheatgrass
		Transmission Line Characteristics														
		Transmission Line as a Whole Function (Rating row)														
Construction		R.O.W. Clearance														
		Access Roads - Temporary or Permanent														
		Staging Site														
		Construction Camp Site (if any)														
		Foundation Digging														
		Tower Erection														
		Conductor Stringing														
		(Rating row)	1	2	1	2	2	2	1	1	1	2	1	1	1	3
		Construction Crew (Rating row)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operation	Physical	Right-of-Way														
		Tower Form I - Self Support														
		Tower Form II - Guyed Wire														
		Conductor														
		(Rating row)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Electrical	Electrostatic														
		Electrochemical														
		Electromagnetic														
		Radio Interference														
		TV Interference														
		Other Communication Related Interference														
		Audible Noise														
		Heat														
		(Rating row)	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Maintenance		Regular														
		Emergence														
		(Rating row)	2	3	2	3	3	3	2	2	2	3	2	2	2	3
		Final rating	1	2	1	2	2	2	1	1	1	1	1	1	1	3

			Natural Elements														
			35% Vegetation														
			Vegetation Types 15%														
		Environmental Elements	Big Sagebrush-Western Wheatgrass	Big Sagebrush-Western Wheatgrass-Grama	Big Sagebrush-Western Wheatgrass-Needle and Thread-Grama	Big Sagebrush-Grass	Silver Sagebrush-Greasewood	Alpine	Bluebunch Wheatgrass-Fescue	Bluebunch Wheatgrass-Needle and Thread	Western Wheatgrass-Needle and Thread-Green Needlegrass	Western Wheatgrass-Needle and Thread-Grama	Needle and Thread-Western Wheatgrass-Grama	Needle and Thread-Sand Dropseed	Grama-Needle and Thread	Near Pristine Vegetation
		Transmission Line Characteristics														
		Transmission Line as a Whole Function (Rating row)														
Construction		R.O.W. Clearance														
		Access Roads - Temporary or Permanent														
		Staging Site														
		Construction Camp Site (if any)														
		Foundation Digging														
		Tower Erection														
		Conductor Stringing														
		(Rating row)	3	3	3	3	3	1	2	2	2	2	2	2	2	1
		Construction Crew (Rating row)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Operation	Physical	Right-of-Way														
		Tower Form I - Self Support														
		Tower Form II - Guyed Wire														
		Conductor														
		(Rating row)	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Electrical	Electrostatic														
		Electrochemical														
		Electromagnetic														
		Radio Interference														
		TV Interference														
		Other Communication Related Interference														
		Audible Noise														
		Heat														
		(Rating row)	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Maintenance		Regular														
		Emergence														
		(Rating row)	3	3	3	3	3	2	3	3	3	3	3	3	3	1
		Final rating	3	3	3	3	2	1	2	2	2	2	2	2	2	1

			Natural Elements												
			35% Vegetation							30% Wildlife					
			Timber Size 10%				Stocking 10%			Mammals					
										General Distribution 5%					
		Environmental Elements	Greater than 9" d.b.h.	9"-5" d.b.h.	Less than 5" d.b.h.	Damaged Stand	Well Stocked	Medium Stocked	Poor Stocked	Elk	Whitetail Deer	Pronghorn Antelope	Mountain Goat	Bighorn Sheep	Moose
		Transmission Line Characteristics													
		Transmission Line as a Whole Function (Rating row)													
Construction		R.O.W. Clearance													
		Access Roads - Temporary or Permanent													
		Staging Site													
		Construction Camp Site (if any)													
		Foundation Digging													
		Tower Erection													
		Conductor Stringing													
		(Rating row)	3	2	2	3	1	2	3	1	2	2	1	1	1
		Construction Crew (Rating row)	0	0	0	0	0	0	0	2	3	3	3	3	3
Operation	Physical	Right-of-Way													
		Tower Form I - Self Support													
		Tower Form II - Guyed Wire													
		Conductor													
		(Rating row)	0	0	0	0	0	0	0	X	X	X	X	X	X
	Electrical	Electrostatic													
		Electrochemical													
		Electromagnetic													
		Radio Interference													
		TV Interference													
		Other Communication Related Interference													
		Audible Noise													
		Heat													
		(Rating row)	X	X	X	X	X	X	X	X	X	X	X	X	X
Maintenance		Regular													
		Emergence													
		(Rating row)	2	3	3	3	2	3	3	2	3	3	2	2	2
		Final rating	3	2	2	3	1	2	3	1	2	2	1	1	1

			Natural Elements														
			30% Wildlife														
			Mammals							Birds 5%							
			Critical Areas 20%														
		Environmental Elements	Elk	Mule Deer	Whitetail Deer	Pronghorn Antelope	Mountain Goat	Bighorn Sheep	Moose	Ring Necked Pheasant-General Distribution	Merriam's Turkey-General Distribution	Waterfowl-Breeding Areas	Sage Grouse-Wintering Area	Sage Grouse-Strutting Ground	Sharptail Grouse-Wintering Area	Sharptail Grouse-Dancing Ground
		Transmission Line Characteristics														
		Transmission Line as a Whole Function (Rating row)														
Construction		R.O.W. Clearance														
		Access Roads - Temporary or Permanent														
		Staging Site														
		Construction Camp Site (if any)														
		Foundation Digging														
		Tower Erection														
		Conductor Stringing														
		(Rating row)	1	1	1	1	1	1	1	2	2	1	1	1	1	1
		Construction Crew (Rating row)	2	3	3	3	3	3	3	3	3	3	3	2	3	2
Operation	Physical	Right-of-Way														
		Tower Form I - Self Support														
		Tower Form II - Guyed Wire														
		Conductor														
		(Rating row)	X	X	X	X	X	X	X	X	X	2	X	1	X	1
	Electrical	Electrostatic														
		Electrochemical														
		Electromagnetic														
		Radio Interference														
		TV Interference														
		Other Communication Related Interference														
		Audible Noise														
		Heat														
		(Rating row)	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Maintenance		Regular														
		Emergence														
		(Rating row)	1	2	2	2	2	2	2	3	3	2	1	1	1	1
		Final rating	1	1	1	1	1	1	1	2	2	1	1	1	1	1

			10% Rangeland									
			Range Types					Range Conditions				
		Environmental Elements	Grassland	Sagebrush	Timber Range	Broad leaf	Barren (Badland)	Excellent	Good	Fair	Poor	Very Poor
		Transmission Line Characteristics										
		Transmission Line as a Whole Function (Rating row)										
Construction		R.O.W. Clearance										
		Access Roads - Temporary or Permanent										
		Staging Site										
		Construction Camp Site (if any)										
		Foundation Digging										
		Tower Erection										
		Conductor Stringing										
		(Rating row)	2	3	2	2	1	3	3	2	2	1
		Construction Crew (Rating row)	0	0	0	0	0	0	0	0	0	0
Operation	Physical	Right-of-Way										
		Tower Form I - Self Support										
		Tower Form II - Guyed Wire										
		Conductor										
		(Rating row)	0	0	0	0	0	0	0	0	0	0
	Electrical	Electrostatic										
		Electrochemical										
		Electromagnetic										
		Radio Interference										
		TV Interference										
		Other Communication Related Interference										
		Audible Noise										
		Heat										
		(Rating row)	0	0	0	0	0	0	0	0	0	0
Maintenance		Regular										
		Emergence										
		(Rating row)	3	3	3	3	2	3	3	3	2	2
		Final rating	2	3	2	2	1	3	3	2	2	1

Figure 40 Matrix for Alignment of Least Damage to Natural Ecological System

TRANSMISSION CORRIDOR STUDY MATRIX

Model Type: ____________________

Rating Categories:
6 = Very Compatible
5 = Compatible
4 = Moderate Compatible
3 = Moderate Incompatible
2 = Incompatible
1 = Very Incompatible
0 = No Relation

				Seismic Risk			Physiography 35 %																			Hydrology 5 %				Sediment Risk 5 %			Timber Size 5 %				Stocking 5 %		
		Environmental Elements																									Stream												
		Transmission Line Characteristics	Geologic Hazard Areas	Zone 1 - Slight Risk	Zone 2 - Mod. Risk	Zone 3 - Major Risk	Mountain - 1	Mountain - 2	Mountain - 3	Mountain - 4	Mountain - 5	Foothill - 1	Foothill - 2	Foothill - 3	Foothill - 4	Basins - 1	Basins - 2	Plains - 1	Plains - 2	Plains - 3	Plains - 4	Plains - 5	Plains - 6	Alluvial - 1	Alluvial - 2	Lakes & Reservoirs	Major	Minor	Intermittent	Severe	Moderate	Slight	Greater than 9" d.b.h.	9"-5" d.b.h.	Less than 5" d.b.h.	Damaged Stand	Well Stocked	Medium Stocked	Poor Stocked
Transmission Line as a Whole		Function (Rating row)																																					
Construction		R.O.W. Clearance																																					
		Access Roads - Temporary or Permanent																																					
		Staging Site																																					
		Construction Camp Site (if any)																																					
		Foundation Digging																																					
		Tower Erection																																					
		Conductor Stringing																																					
		(Rating row)																																					
		Construction Crew (Rating row)																																					
Operation	Physical	Right-of-Way																																					
		Tower Form I - Self Support																																					
		Tower Form II - Guyed Wire																																					
		Conductor																																					
		(Rating row)																																					
	Electrical	Electrostatic																																					
		Electrochemical																																					
		Electromagnetic																																					
		Radio Interference																																					
		TV Interference																																					
		Other Communication Related Interference																																					
		Audible Noise																																					
		Heat																																					
		(Rating row)																																					
Maintenance		Regular																																					
		Emergence																																					
		(Rating row)																																					
		Final rating					1	3	2	2	1	3	5	2	4	5	3	5	4	2	3	4	3	6	3		3	5	6	1	4	6	1	4	6	0	1	3	6

			Cultural Elements																											
			Existing Land Use																											
			15 %									Rangeland										Transportation 15 %								
												Range Types					Range Conditions						Highway					Airport		
		Transmission Line Characteristics	Urban Areas	Small Communities	Scattered Built-up Areas	Industrial Areas	Industrial Sites	Irrigated Land	Dry Crop Land	Commercial Woodland	Non-Commercial Woodland	Grassland	Sagebrush	Timber Range	Broad leaf	Barren (Badland)	Excellent	Good	Fair	Poor	Very Poor	Railroads	Freeway	Paved Highway	Graveled	Unsurfaced	Primitive	Public - Large	Public - Small	Private
Transmission Line as a Whole		Function (Rating row)										6																		
Construction		R.O.W. Clearance																												
		Access Roads - Temporary or Permanent																												
		Staging Site																												
		Construction Camp Site (if any)																												
		Foundation Digging																												
		Tower Erection																												
		Conductor Stringing																												
		(Rating row)																												
		Construction Crew (Rating row)																												
Operation	Physical	Right-of-Way																												
		Tower Form I - Self Support																												
		Tower Form II - Guyed Wire																												
		Conductor																												
		(Rating row)																												
	Electrical	Electrostatic																												
		Electrochemical																												
		Electromagnetic																												
		Radio Interference																												
		TV Interference																												
		Other Communication Related Interference																												
		Audible Noise																												
		Heat																												
		(Rating row)																												
Maintenance		Regular																												
		Emergence																												
		(Rating row)																												
		Final rating	1	2	3	2	1	4	5	4	5											3	2	4	5	6	6			

			Cultural Elements																																		
			Existing Land Use																																Potential Land Use (Partial)	
			Utility 10 %																Communication 1 %						Recreation 2 %											2 %	
			Power Plant			Electric Transmission Lines															TV Signal Strength		Radio Signal Strength														
		Transmission Line Characteristics	Hydro Plant	Thermal Plant	Substation	500 KV	230 KV	161 KV	115 KV	100 KV	69 KV	57 KV	50 KV	34.5 KV	Gas Pipeline	Oil Pipeline	Refined Products Pipeline	Refinery	TV Station	Radio Station	Grade A	Grade B	Primary Coverage	Secondary Coverage	State Park	County/City Park	Campground	Other Terrestrial Related Activities - Natural Environment Oriented	Other Terrestrail Related Activities - Cultural Environment Oriented	Other Water Related Activities	Point of Interest	Scenic Roadway	National Register Historic Site	Other Historic Site	Archaeological Site	Potential Irrigable Land	Potential Recreation Land
Transmission Line as a Whole		Function (Rating row)																																			
Construction		R.O.W. Clearance																																			
		Access Roads - Temporary or Permanent																																			
		Staging Site																																			
		Construction Camp Site (if any)																																			
		Foundation Digging																																			
		Tower Erection																																			
		Conductor Stringing																																			
		(Rating row)																																			
		Construction Crew (Rating row)																																			
Operation	Physical	Right-of-Way																																			
		Tower Form I - Self Support																																			
		Tower Form II - Guyed Wire																																			
		Conductor																																			
		(Rating row)																																			
	Electrical	Electrostatic																																			
		Electrochemical																																			
		Electromagnetic																																			
		Radio Interference																																			
		TV Interference																																			
		Other Communication Related Interference																																			
		Audible Noise																																			
		Heat																																			
		(Rating row)																																			
Maintenance		Regular																																			
		Emergence																																			
		(Rating row)																																			
		Final rating					4	4	4	4									1	1	3	2	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3

Figure 41 Matrix for Alignment of Least Construction Cost

TRANSMISSION CORRIDOR STUDY MATRIX

Model Type: ____________________

Rating Categories:
6 = Very Compatible
5 = Compatible
4 = Moderate Compatible
3 = Moderate Incompatible
2 = Incompatible
1 = Very Incompatible
0 = No Relation

Environmental Elements		Natural Elements																																		
		Vegetation																																		
		Vegetation Types (1/3)																											Timber Size (1/3)				Stocking (1/3)		
Transmission Line Characteristics		Subalpine	Lodgepole Pine	Spruce - Fir	Western Larch	Douglas fir	Western Ponderosa Pine	Eastern Ponderosa Pine	Ponderosa Pine Savannah	Limber Pine - Juniper	Juniper Complex	Cottonwood-Willow-Dogwood	Cottonwood-Willow	Boxelder-Green Ash-Pose-Chokecherry	Big Sagebrush-Bluebunch Wheatgrass	Big Sagebrush-Western Wheatgrass	Big Sagebrush-Western Wheatgrass-Grama	Big Sagebrush-Western Wheatgrass-Needle and Thread-Grama	Big Sagebrush-Grass	Silver Sagebrush-Greasewood	Alpine	Bluebunch Wheatgrass-Fescue	Bluebunch Wheatgrass-Needle and Thread	Western Wheatgrass-Needle and Thread-Green Needlegrass	Western Wheatgrass-Needle and Thread-Grama	Needle and Thread-Western Wheatgrass-Grama	Needle and Thread-Sand Dropseed	Grama-Needle and Thread	Near Pristine Vegetation	Greater than 9" d.b.h.	9"-5" d.b.h.	Less than 5" d.b.h.	Damaged Stand	Well Stocked	Medium Stocked	Poor Stocked
Transmission Line as a Whole	Function (Rating row)																																			
Construction	R.O.W. Clearance																																			
	Access Roads - Temporary or Permanent																																			
	Staging Site																																			
	Construction Camp Site (if any)																																			
	Foundation Digging																																			
	Tower Erection																																			
	Conductor Stringing																																			
	(Rating row)																																			
	Construction Crew (Rating row)																																			
Operation – Physical	Right-of-Way																																			
	Tower Form I - Self Support																																			
	Tower Form II - Guyed Wire																																			
	Conductor																																			
	(Rating row)																																			
Operation – Electrical	Electrostatic																																			
	Electrochemical																																			
	Electromagnetic																																			
	Radio Interference																																			
	TV Interference																																			
	Other Communication Related Interference																																			
	Audible Noise																																			
	Heat																																			
	(Rating row)																																			
Maintenance	Regular																																			
	Emergence																																			
	(Rating row)																																			
	Final rating	3	2	2	2	2	2	2	3	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3	1	2	3

Figure 42 Matrix for Alignment of Least Disruption to Existing Forestry Production

TRANSMISSION CORRIDOR STUDY MATRIX

Model Type: ______________________

Rating Categories:
6 = Very Compatible
5 = Compatible
4 = Moderate Compatible
3 = Moderate Incompatible
2 = Incompatible
1 = Very Incompatible
0 = No Relation

								50%	30%			20% Rangeland									
												15% Range Types					5% Range Conditions				
		Environmental Elements	Urban Areas	Small Communities	Scattered Built-up Areas	Industrial Areas	Industrial Sites	Irrigated Land	Dry Crop Land	Commercial Woodland	Non-Commercial Woodland	Grassland	Sagebrush	Timber Range	Broad leaf	Barren (Badland)	Excellent	Good	Fair	Poor	Very Poor
Transmission Line Characteristics																					
Transmission Line as a Whole Function		(Rating row)																			
Construction		R.O.W. Clearance																			
		Access Roads - Temporary or Permanent																			
		Staging Site																			
		Construction Camp Site (if any)																			
		Foundation Digging																			
		Tower Erection																			
		Conductor Stringing																			
		(Rating row)																			
		Construction Crew (Rating row)																			
Operation	Physical	Right-of-Way																			
		Tower Form I - Self Support																			
		Tower Form II - Guyed Wire																			
		Conductor																			
		(Rating row)																			
	Electrical	Electrostatic																			
		Electrochemical																			
		Electromagnetic																			
		Radio Interference																			
		TV Interference																			
		Other Communication Related Interference																			
		Audible Noise																			
		Heat																			
		(Rating row)																			
Maintenance		Regular																			
		Emergence																			
		(Rating row)																			
		Final rating						2	2			2	3	3	2	0	3	3	3	2	2

Figure 43 Matrix for Alignment of Least Disruption to Existing Agricultural Production

TRANSMISSION CORRIDOR STUDY MATRIX

Model Type: ____________________

Rating Categories:
6 = Very Compatible
5 = Compatible
4 = Moderate Compatible
3 = Moderate Incompatible
2 = Incompatible
1 = Very Incompatible
0 = No Relation

			Cultural Elements																							
			Existing Land Use																							
			30% Transportation									70% Utility															
				Highway					Airport			Power Plant			Electric Transmission Lines												
Transmission Line Characteristics		Environmental Elements	Railroads	Freeway	Paved Highway	Graveled	Unsurfaced	Primitive	Public - Large	Public - Small	Private	Hydro Plant	Thermal Plant	Substation	500 KV	230 KV	161 KV	115 KV	100 KV	69 KV	57 KV	50 KV	34.5 KV	Gas Pipeline	Oil Pipeline	Refined Products Pipeline	Refinery
Transmission Line as a Whole		Function (Rating row)																									
Construction		R.O.W. Clearance																									
		Access Roads - Temporary or Permanent																									
		Staging Site																									
		Construction Camp Site (if any)																									
		Foundation Digging																									
		Tower Erection																									
		Conductor Stringing																									
		(Rating ow)																									
		Construction Crew (Rating row)																									
Operation	Physical	Right-of-Way																									
		Tower Form I - Self Support																									
		Tower Form II - Guyed Wire																									
		Conductor																									
		(Rating row)																									
	Electrical	Electrostatic																									
		Electrochemical																									
		Electromagnetic																									
		Radio Interference																									
		TV Interference																									
		Other Communication Related Interference																									
		Audible Noise																									
		Heat																									
		(Rating row)																									
Main-tenance		Regular																									
		Emergence																									
		(Rating row)																									
		Final rating	2	3	3	4	4	4	1	1	1	6	6	6	0	6	6	6	6	5	5	5	5	0	0	0	

Figure 44 Matrix for Alignment of Maximum Utilization of Existing Right-of-Way

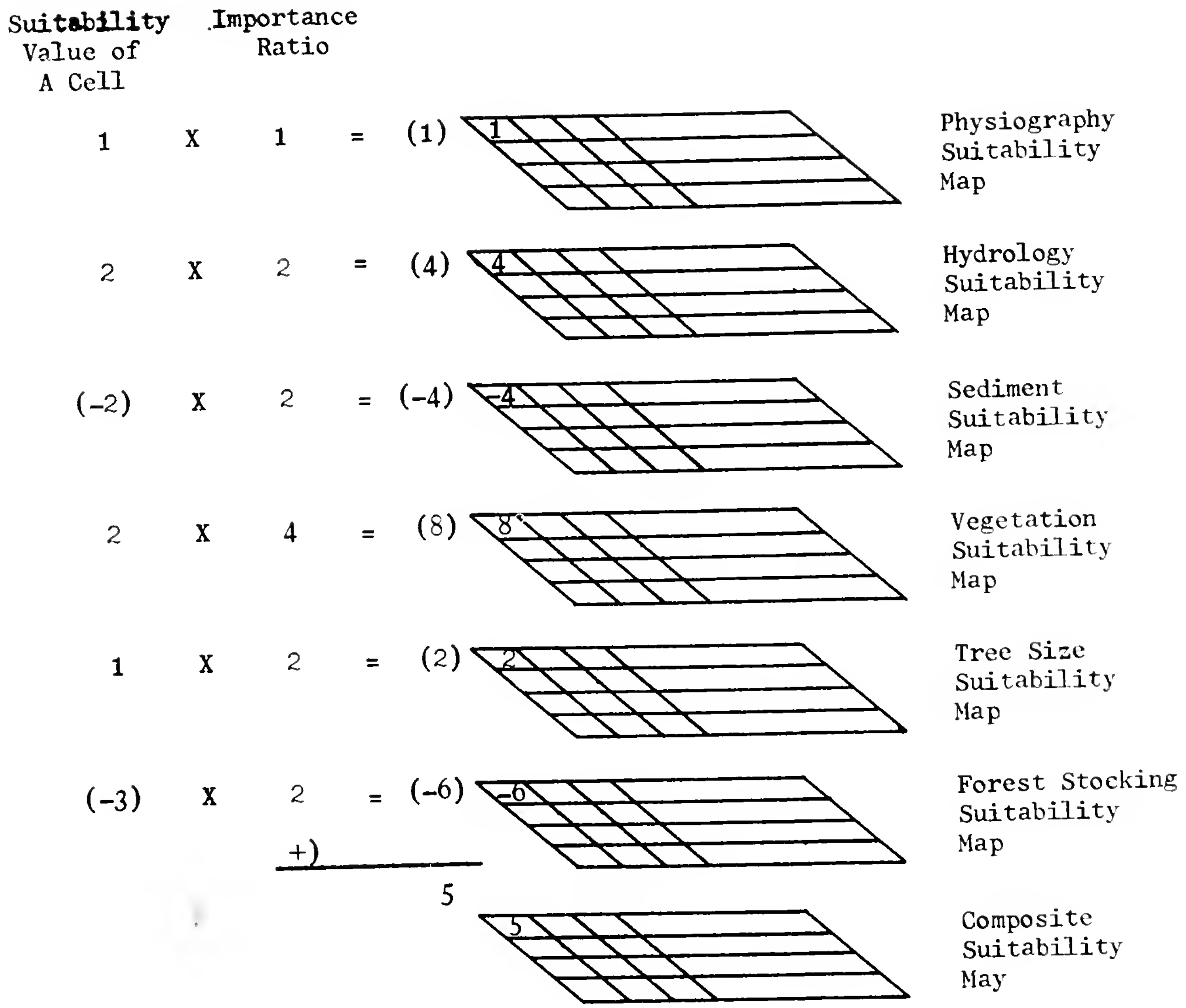


Figure 45

possible corridor may be revealed. Otherwise, greater subjectivity must be employed, although certain guidelines for minimizing impacts can be used. Therefore, various patterns of comparison between concerns ought to be tested in order to obtain a final corridor.

Corridor selection through comparison can be materialized by combining (or overlapping) various concerns with different ratings. Only a computer can conduct such a massive and lengthy combination process efficiently.

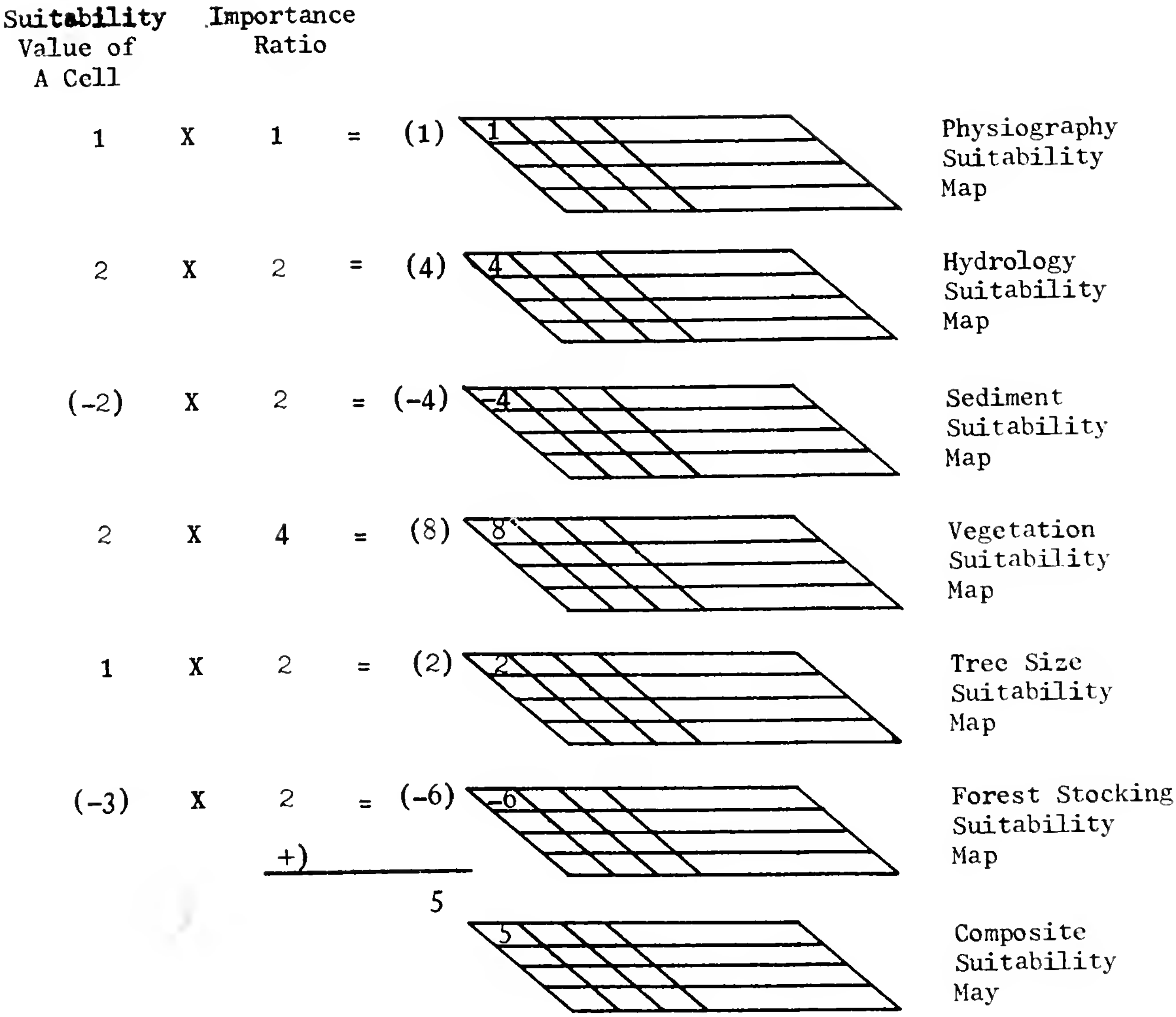
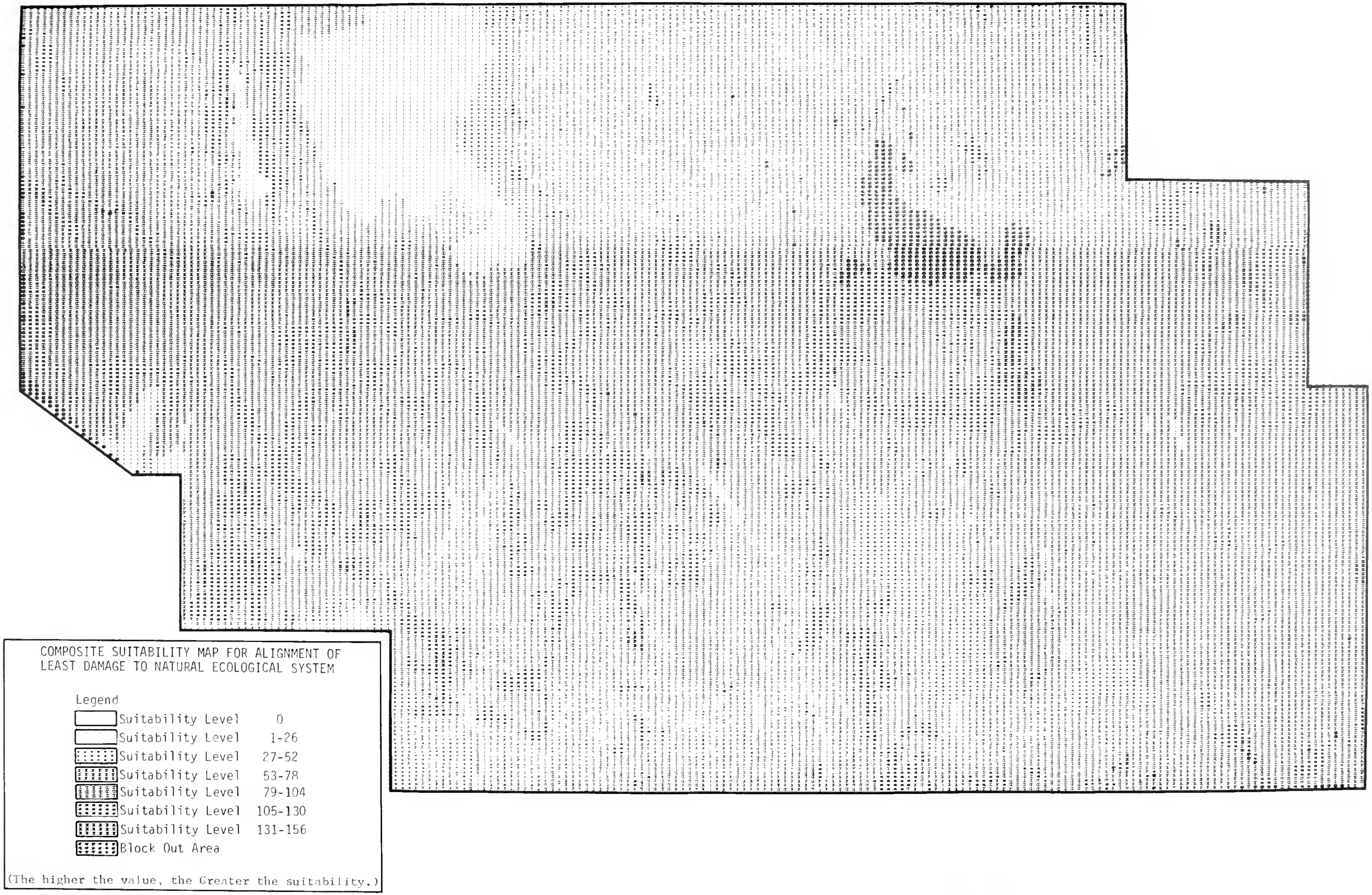


Figure 45

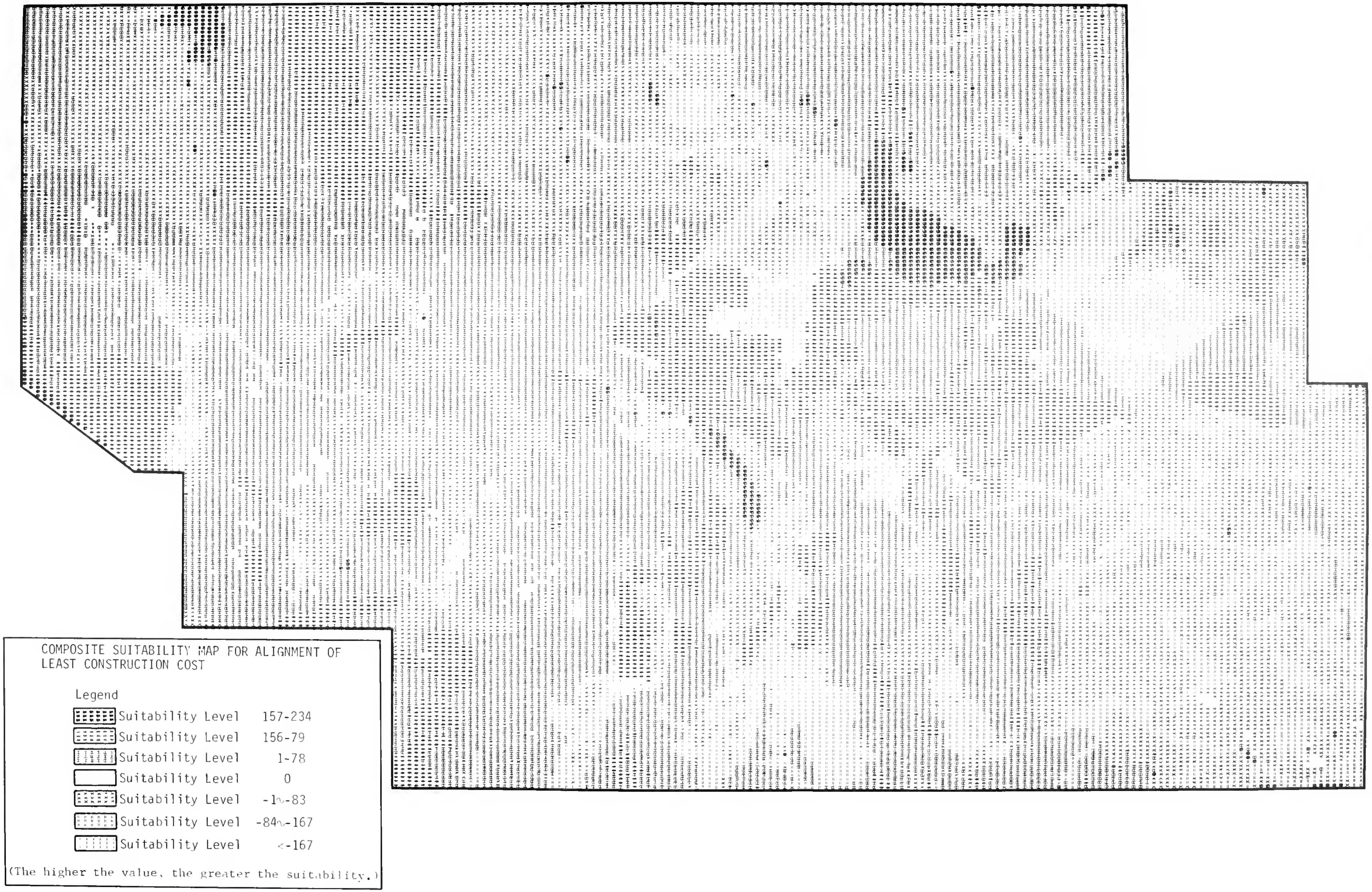
possible corridor may be revealed. Otherwise, greater subjectivity must be employed, although certain guidelines for minimizing impacts can be used. Therefore, various patterns of comparison between concerns ought to be tested in order to obtain a final corridor.

Corridor selection through comparison can be materialized by combining (or overlapping) various concerns with different ratings. Only a computer can conduct such a massive and lengthy combination process efficiently.



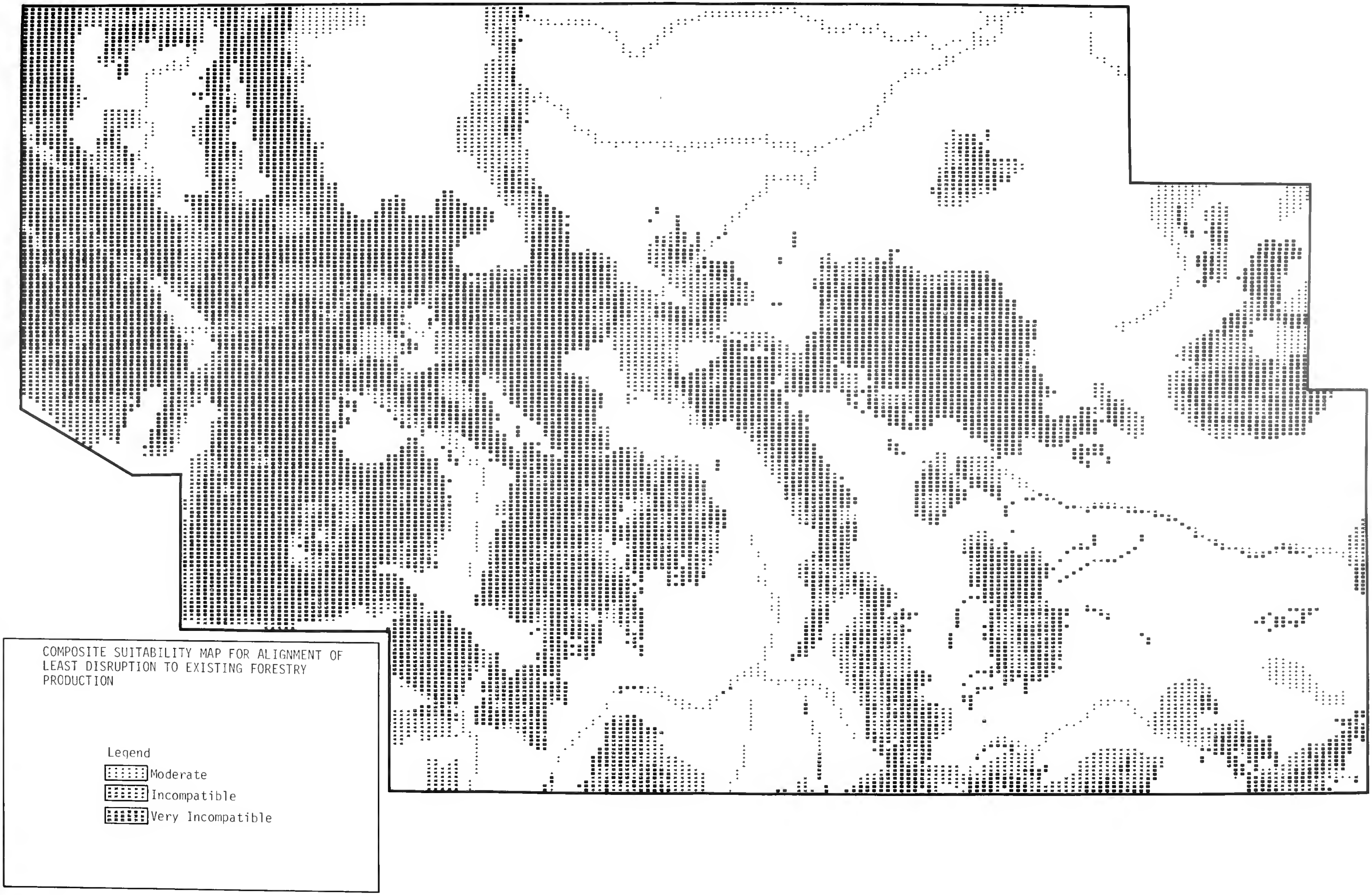
COMPOSITE SUITABILITY MAP FOR ALIGNMENT OF LEAST DAMAGE TO NATURAL ECOLOGICAL SYSTEM

(The higher the value, the Greater the suitability.)

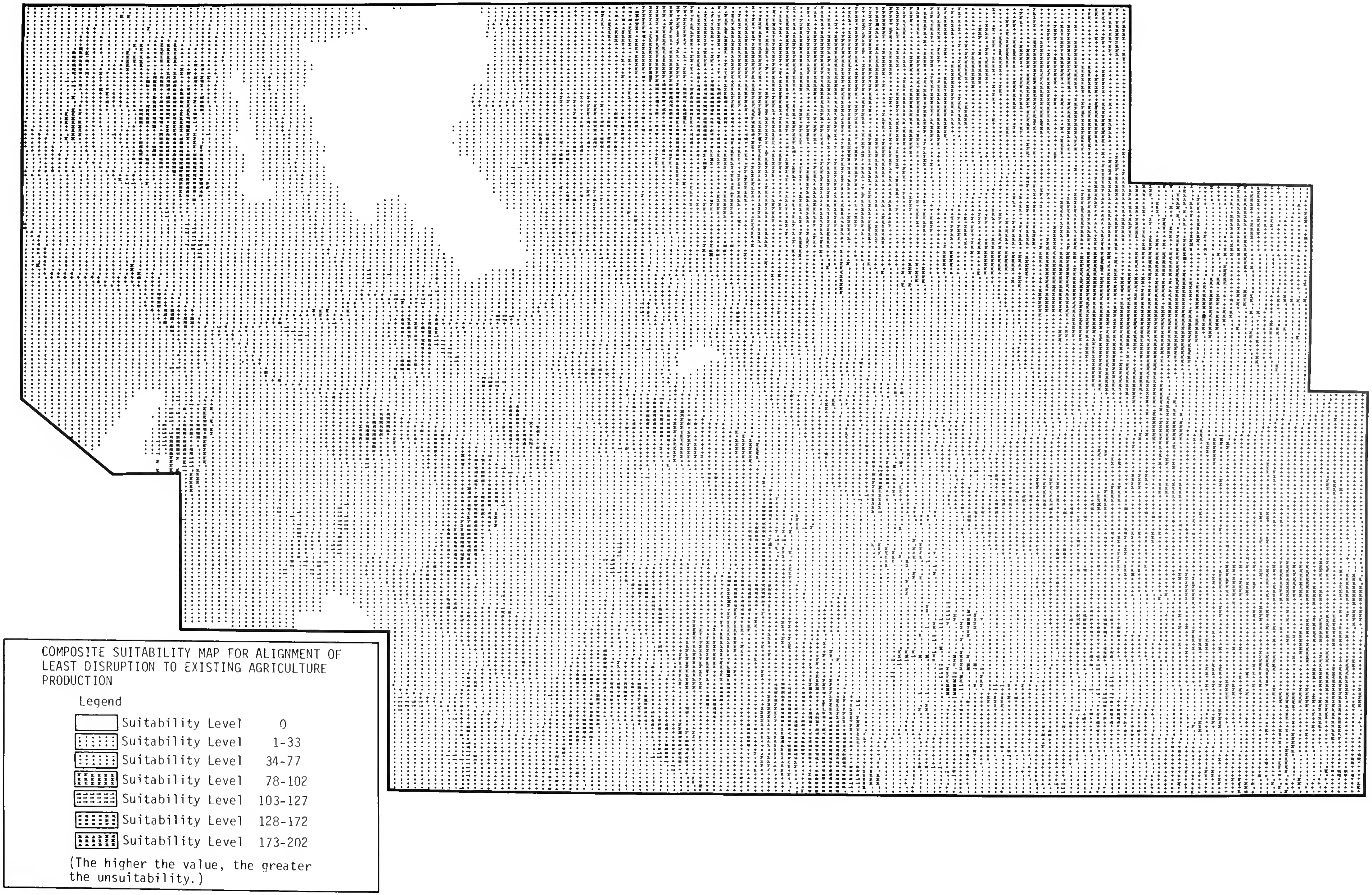


COMPOSITE SUITABILITY MAP FOR ALIGNMENT OF LEAST CONSTRUCTION COST

(The higher the value, the greater the suitability.)



COMPOSITE SUITABILITY MAP FOR ALIGNMENT OF LEAST DISRUPTION TO EXISTING FORESTRY PRODUCTION



COMPOSITE SUITABILITY MAP FOR ALIGNMENT OF LEAST DISRUPTION TO EXISTING AGRICULTURE PRODUCTION

Legend

☐	Suitability Level	0
░	Suitability Level	1-33
░	Suitability Level	34-77
▦	Suitability Level	78-102
▤	Suitability Level	103-127
▥	Suitability Level	128-172
▩	Suitability Level	173-202

(The higher the value, the greater the unsuitability.)

COMPOSITE SUITABILITY MAP FOR ALIGNMENT OF
MAXIMUM UTILIZATION OF EXISTING RIGHT-OF-WAY

Legend

⁙ Suitability Level 3
☐ Suitability Level 0
▦ Suitability Level -3
▩ Suitability Level -18
░ Suitability Level -21
▥ Suitability Level -24

(The higher the value, the greater the suitability.)

APPENDIX I
PARTIAL LIST OF MANUFACTURERS

MANUAL DIGITIZER

1) The Bendix Corporation, Computer Graphics
23850 Freeway Park Drive
Farmington, MI 48024
Tel. (313) 477-3700

2) California Computer Products, Inc. (CALCOMP)
2411 W. La Palma Avenue
Anaheim, CA 92801
Tel. (714) 821-2011

3) Calma Company
707 Kifer Road
Sunnyvale, CA 94086
Tel. (408) 245-7522

4) Data Technology, Inc. (a subsidiary of the Allen-Bradley Company)
65 Grove Street
Watertown, MA 07172
Tel. (617) 924-1773

5) H. Dell Foster Company
803 W. Broad Street
Falls Church, VA 22046
Tel. (703) 534-7742

6) Instronics Limited
P. O. Box 100
Stittsville, Ontario, Canada
or
Suite 204, Bridge Plaza,
Ogdensburg, NY 13669

AUTOMATIC DIGITIZER (All the following described features are claimed by the manufacturer.)

1) Actron Industries, Inc. (a subsidiary of McDonnell Douglas Corporation)
700 Royal Oaks Dr.
Monrovia, CA 91016

Model Type: ALTAPE/ALDRAFT MKIII

Digitizing and Drafting Size: 5' x 4' to 5' x 24' flat bed table with vacuum holddown

Digitizing Modes: Automatic or manual continuous tracing or "point picking" for digitizing straight line segments and hole location

Digitizing Accuracy: ± 0.001 inch from center of smooth line of width 0.003 to 0.025 inch, or ± 0.003 inch from edge of light/dark area

Digitizing Speed: 50 ipm digitizing; 600 ipm slewing

Overall Accuracy: ± 0.004 inch for 5' x 12' table

Drafting Performance: Accuracy of ± 0.004 inch, repeatability ± 0.002 inch for standard 5' x 12' table at 600 ipm drafting speed

2) IBM CorporationFederal Systems Division,
Gaithersburg, MD 20760
Systems Development Division,
Kingston, NY 12401

Model Type: Experimental Scanner/Plotter (not for commercial sale)

Digitizing Size: 24" x 30"

Resolution: Up to 1000 samples per inch

Input Documents: Black/white, continuous gray tone, or color pencil

For detail specification and software capability see: *System and Design Study for an Advanced Drum Plotter - Final Technical Report* (Contract No. DAAK-02-69-C-0015), April 1970, and *Cartographic Scanner/Plotter (U) - Final Technical Report* (Contract No. DAAK 07-71-C-0139), July 1972

3) Calspan Corporation
Computer Systems Department
P.O. Box 235
Buffalo, NY 14221
Tel. (716) 632-7500

Drum Scanner

4) Broomall Industries, Inc.
682 Parkway
Broomall, PA 19008
Tel. (215) 353-4010

Model Type: GP-100 Graphics Processing System

Digitizing Size: 11" x 25"

Scan Resolution: 0.0025", 0.005", 0.01"

Color Separation: Black/White 1 or 2 level differentiation or 4 bits, 16 gray levels or 1 or 2 level differentiation or 4 color selectable plus 4 bits, 16 gray levels for each selected color

5) Dicomed Corporation
9700 Newton Avenue So.
Minneapolis, MN 55431
Tel. (612) 888-1900

Image Scanner Model D series

Digitizing Size: From 11 x 11 mm to 14" x 14"

Scan Matrix Resolution: 2048 x 2048, 1024 x 1024, 512 x 512, or 256 x 256 points.

6) Perkin - Elmer, Boller & Chivens Division
619 Meridia Avenue
South Pasadena, CA 91030
Tel. (213) 682-3391

Model Type: PDS Model 1010A Microdensitometer

Sample Size: 10" x 10"

Resolution: Greater than 600 L/mm at 100 x magnification

7) Image Analysing Computers (IMANCO) (a division of Metals Research Instrument Corporation)
40 Robert Pitt Drive
Monsey, NY 10952
Tel. (914) 356-331

8) Bausch & Lomb
635 St. Paul Street
Rochester, NY 14602
Tel. (716) 232-6000

Photo Data Quantizer

9) Optronics International, Inc.
7 Stuart Road
Chelmsford, MA 01823
Tel. (617) 256-4511

10) Spatial Data System, Inc.
P. O. Box 249
500 S. Fairview Avenue
Goleta, CA 93017
Tel. (805) 967-2383

Microdensitometer Model 704-12 (12 color unit) Model 703-73 (32 color unit)

BIBLIOGRAPHY

AFIPS Conference Proceedings. 1971 Fall Joint Computer Conference, Volume 39. Las Vegas, Nevada: AFIPS Press, November 16-18, 1971.

Alsberg, Peter A., and others. *NARIS: A Natural Resource Information System.* Urbana-Champaign, Illinois: Center for Advanced Computation.

Archer, Bruce L. "Systematic Method for Designer," *Design.* 172/pp. 46-49, 174/pp. 70-73, 176/pp. 52-57, 197/pp. 68-72, 185. 1963-1964.

Arms, Samuel. *Map/Model System - System Description and User's Guide.* Eugene, Oregon: Bureau of Governmental Research and Service, May 1970.

Belknap, Raymond K., and Furtado, John G. *Three Approaches to Environmental Resource Analysis.* Washington, D.C.: The Conservation Foundation, 1967.

Brown, Harrison. *The Challenge of Man's Future.* New York: The Viking Press, 1956 (Eighteenth Printing 1970).

Chapin, F. Stuart, Jr., and Weiss, Shirley F. *Factors Influencing Land Development.* Chapel Hill, N.C.: Urban Study Program, University of North Carolina, August 1962.

Childress, L. S.; Gagnon, T. E.; Gurwitz, D.: Thompson, D. R.; and Czjakowski, A. *Cartographic Scanner/Plotter (U).* Final Technical Report of the U.S. Army Engineer Topographic Laboratories. Gaithersburg, Maryland: IBM Corp., Federal Systems Division, July 1972.

Commission of Geographical Data Sensing and Processing. *Geo-Information Systems and the Use of Computers in Handling Land Use Information.* R. F. Tomlinson, Chairman. (Mimeographed)

Comprehensive Planning Organization. *Polygon Information Overlay System.* San Diego, California: Boeing Computer Services, Inc., September 15, 1971.

Darling, F. Fraser, and Milton, John P., ed. *Future Environment of North America.* Garden City, New York: The Natural History Press, 1966.

Daubenmire, R. F. *Plants and Environment*. New York: John Wiley & Sons, Inc. 1959.

Douglas, G. R. *The Design and Operation of an Automated Hydrographic Data Acquisition and Processing System*. Report of the Bedford Institute of Oceanography. Dartmouth, Nova Scotia, Canada.

Ducker, Kenneth J. *Statewide Land Information Systems; Design Consideration*. Report of the Institute of Urban and Regional Research, Iowa City, Iowa: University of Iowa.

Energy Planning Division, Montana Department of Natural Resources and Conservation. *Draft Environmental Impact Statement on Colstrip Electric Generating Units 3 & 4, 500 Kilovolt Transmission Lines & Associated Facilities*. Helena, Montana: Montana Department of Natural Resources and Conservation, November 1974.

Environmental Systems Research Institute. *Appendix 2: Evaluation of Spatial Identification Techniques for Geographic Data in the Lumap System*. Redlands, California: ERSI. (Mimeographed)

Environmental Systems Research Institute. *Environmental Research Study for Poppet Flat*. Redlands, California: ESRI, June 30, 1972.

Fieser, John B. *CMS Characteristics*. Report of the Economic Development Administration, Office of Planning and Program Support. Washington, D.C.: Economic Administration, February 7, 1972.

Firey, Walter Irving. Man, Mind, and Land -- *A Theory of Resource Use*. Glencoe, Illinois: The Free Press of Glencoe, 1960.

Friar, M. E.; Hogan, R. D.; Min, P. J.; Sharp, J. V.; and Thompson, D. R. *System and Design Study for an Advanced Drum Plotter*. Final Technical Report of the U.S. Army Engineer Topographic Laboratories. Kingston, New York: ABM System Division, April 1970.

Gilpin, S. R.; Sharp, J. V.; and Thompson, D. R. *Color Separation System Evaluation (U)*. Final Technical Report to U.S. Army Engineer Topographic Laboratories. Gaithersburg, Maryland: IBM Corp. Federal Systems Division, January 1968.

Graham, Edward H. The Land and Wildlife. New York: Oxford University Press, 1947.

Graham, Edward H. Natural Principles of Land Use. New York: Oxford University Press, 1944.

Hamilton, H. R., and others. System Simulation for Regional Analysis -- An Application to River-Basin Planning. Cambridge, Massachusetts: The M.I.T. Press, 1969.

Hardy, E. E., and Shelton, R. L. "Inventorying New York's Land Use and Natural Resources." New York's Food and Life Sciences. Vol. 3. No. 4. October-December, 1970.

Hillel, Daniel. Soil and Water, Physical Principles and Processes. New York: Academic Press, 1971.

Hills, George Angus. Developing a Better Environment. Ontario, Canada: Ontario Economic Council, 1970.

Hills, George Angus. The Ecological Basis for Land Use Planning. Research Report No. 46. Ontario,

Information Systems Division, Minnesota Department of Administration. The Minnesota Land Information-System. St. Paul, Minnesota: Minnesota Department of Administration, March 1971.

Johnson, Claude W. Computerized Land Pattern Mapping from Mono-Imagery. Reprinted Report from Proceedings of the Seventh International Symposium on Remote Sensing Environment. Riverside, California: University of California, Dept. of Geography, May 1971.

Jones, J. Christopher. "Design Methods Compared." Design. 212/pp. 32/35, 213/pp. 46-52.

Jones, J. Christopher. "A Method of Systematic Design." Conference on Design Method. New York: Pergamon Press, pp. 53-73, 1963.

Kneese, Allen V.; Ayres, Robert U.; and d'Arge, Ralph C. Economics and the Environment - A Materials Balance Approach. Washington, D.C.: Resources for the Future, Inc., 1970.

MacLeod, M. H. Semi-Automated Large Scale Mapping. A Report presented at the XII Congress - International Society of Photogrammetry. Ottawa, Canada: Ontario Ministry of Transportation and Communications, July-August, 1972.

McHarg, Ian L. Design with Nature. Garden City, New York: Natural History Press, 1969.

McHarg, Ian L. The Least Social Cost Corridor For Richmond Parkway. Project Director: Ian L. McHarg. New York: New York City Department of Parks, 1968.

Min, P. June, and Noland, Brian E. Recognition of Handprinted Symbols for Computer-Aided Mapping System. Kingston, New York: IBM Systems Development Division, December 1971.

Moller, Sven G. A System of Describing and Classifying Information Concerning Land Forms. Stockholm, Sweden: National Swedish Institute for Building Research, December 8, 1972.

Mor, M., and Lamdan, T. "A New Approach to Automatic Scanning of Contour Maps." Association for Computing Machinery, Inc. Volume 15, Number 9. pp. 809-812. September 1972.

Nichols, David A. A Demonstration of the Use of the Grid System Utilizing Multi-Source Inputs. Project THEMIS Technical Report. Riverside, California, August 1971.

Proceedings of the International Expert-Meeting on Data Banks for Development. Data Banks for Development. Saint-Maximin, France, May 24-28, 1971.

Radlinski, W. A. "Keynote Address - International Conference on Automation in Cartography." Reston, Virginia, September 9, 1974.

Raytheon Co. A Proposal to Further Develop and Test a Natural Resource Information System. Wayland, Massachusetts: Raytheon Co. Equipment Division, May 1972.

Report of the Environmental Systems Research Institute. Classification and Review of Coordinate Identification and Computer Mapping Systems. Jack Dangermond, Director. Redlands, California, August 1972.

Report of the General Survey Systems of Statistics Canada. GRDSR: Facts by Small Areas. Report on the Geographically Referenced Data Storate and Retrieval System. Ottawa. Canada: Statistics Canada. June 1972.

Report of the U.S. Army Engineer Topographic Laboratories. Application System Programming Functional Specification. Kingston, New York: IBM Systems Development Division, June 1972.

Report of the U.S. Army Engineer Topographic Laboratories. *Program Description of Application System for Cartographic Development Division*. July 14, 1972.

Report to the U.S. Department of the Interior. *Natural Resource Information System, Vol. I Overall Description*. Seattle, Washington: Boeing Computer Services, Inc., April 28, 1972.

Spinning, John N. *Automated Hydrographic Survey Techniques*. Report to the XI Pan American Consultation on Cartography. Washington D.C.: U.S. Naval Oceanic Office, 1969.

Thomas, William L., Jr., and others. *Man's Role in Changing the Face of the Earth*. Chicago: The University of Chicago Press, 1956.

Tomlinson, R. F., ed. *Geographical Data Handling*. A Publication of the International Geographical Data Sensing and Processing for the UNESCO/IGU Second Symposium on Geographical Information Systems. Volume 1. Ottawa, Canada: IGU Commission on Geo. Data Sensing and Processing, 1972.

U.S. Department of the Army. *IBM Scanner/Plotter Test*. Diazo Copies of the U.S. Army Engineer Topographic Labs. Fort Belvoir, Virginia: Automated Cartography Branch, September 15, 1972.

U.S. Department of Commerce, Bureau of the Census. *Census Use Study. Report No. 2 Computer Mapping*. Washington D.C.: Bureau of the Census, 1969.

U.S. Department of Commerce: Bureau of the Census. *Census Use Study. Report No. 4 The DIME Geocoding System*. Washington, D.C.: Brueau of the Census, 1970.

Wilson, Stephen O.; Beevers, Donald J.; Fullem, Bruce; and Pierson, Nancy. *Potential Recreation and Open Space Areas in New York State*. Albany, N.Y.: New York State Office of Parks and Recreation, July 1970.

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